Draft Environmental Analysis of Marine Geophysical Surveys by the R/V *Marcus G. Langseth* in the Southeast Pacific Ocean, 2016/2017

Prepared for

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ABSTRACT

Researchers from Oregon State University (OSU) and University of Texas at Austin, Institute for Geophysics (UT), with funding from the U.S. National Science Foundation (NSF), propose to conduct high-energy seismic surveys from the Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) in the waters off Chile in the southeast Pacific Ocean for ~80 days in 2016/2017. The NSF-owned *Langseth* is operated by Columbia University's Lamont-Doherty Earth Observatory (L-DEO) under an existing Cooperative Agreement. The proposed seismic surveys would use a towed array of 36 airguns with a total discharge volume of ~6600 in^3. The surveys would take place within the Exclusive Economic Zone (EEZ) and Territorial Waters of Chile in water depths ~50–7600 m. On behalf of L-DEO, the U.S. Department of State is seeking authorization from Chile for clearance to work within its EEZ.

NSF, as the funding and action agency, has a mission to "promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…". The proposed seismic surveys would collect data in support of research proposals that have been reviewed under the NSF merit review process and identified as NSF program priorities. They would provide data necessary to image regions of the Chile margin that have slipped in the past and recently, as during the 2014 Pisagua/Iquique and 2015 Illapel earthquakes. The geologic environment of Chile is similar to that of the U.S. Pacific Northwest, and a better understanding of the relationship between geologic structure and earthquake activity in Chile would provide information important for anticipating future earthquake activity in the Pacific Northwest and elsewhere.

This Draft Environmental Analysis (EA) addresses NSF's requirements under Executive Order 12114, "Environmental Effects Abroad of Major Federal Actions", for the proposed NSF federal action. As operator of the *Langseth*, L-DEO, on behalf of itself, NSF, OSU, and UT, is requesting an Incidental Harassment Authorization (IHA) from the U.S. National Marine Fisheries Service (NMFS) to authorize the incidental, i.e., not intentional, harassment of small numbers of marine mammals should this occur during the seismic surveys. The analysis in this document supports the IHA application process and provides information on marine species that are not addressed by the IHA application, including sea turtles, seabirds, fish, and invertebrates that are listed under the U.S. Endangered Species Act (ESA), including candidate species. As analysis on endangered/threatened species was included, this document will also be used to support ESA Section 7 consultations with NMFS and the U.S. Fish and Wildlife Service (USFWS). Alternatives addressed in this EA consist of the Propposed Action with issuance of an associated IHA and the No Action alternative, with no IHA and no seismic surveys. This document tiers to the Programmatic Environmental Impact Statement/Overseas Environmental Impact Statement for Marine Seismic Research Funded by the National Science Foundation or Conducted by the U.S. Geological Survey (June 2011) and Record of Decision (June 2012), referred to herein as PEIS.

Numerous species of marine mammals inhabit the southeast Pacific Ocean. Several of these species are listed as ***Endangered*** under the ESA: the southern right, humpback, sei, fin, blue, and sperm whales, and the marine otter. Other marine ESA-listed species that could occur in the area include the ***Endangered*** leatherback and loggerhead turtles; the ***Threatened*** green and olive ridley turtles; the ***Threatened*** Humboldt penguin; and the ***Endangered*** scalloped hammerhead shark. The common thresher shark, bigeye thresher shark, porbeagle shark, smooth hammerhead shark, and greytail skate are ***candidate species*** for ESA listing that could occur in the area.

Potential impacts of the proposed seismic surveys on the environment would be primarily a result of the operation of the airgun array. A multibeam echosounder and sub-bottom profiler would also be operated during the surveys. Impacts from the Proposed Action would be associated with increased underwater noise, which could result in avoidance behavior by marine mammals, sea turtles, seabirds, and fish, and other forms of disturbance. An integral part of the planned surveys is a monitoring and mitigation program designed to minimize potential impacts of the proposed activities on marine animals present during the proposed surveys, and to document as much as possible the nature and extent of any effects. Injurious impacts to marine mammals, sea turtles, and seabirds have not been proven to occur near airgun arrays or the other types of sound sources to be used. However, a precautionary approach would still be taken, and the planned monitoring and mitigation measures would reduce the possibility of any effects.

Protection measures designed to mitigate the potential environmental impacts to marine mammals and sea turtles would include the following: ramp ups; typically two (but a minimum of one) dedicated observers maintaining a visual watch during all daytime airgun operations; two observers before and during ramp ups during the day; no start ups during poor visibility or at night unless at least one airgun has been operating; passive acoustic monitoring (PAM) via towed hydrophones during both day and night to complement visual monitoring; and power downs (or if necessary shut downs) when marine mammals or sea turtles are detected in or about to enter designated exclusion zones. The acoustic source would also be powered or shut down in the event an ESA-listed seabird were observed diving or foraging within the designated exclusion zones. Observers would also watch for any impacts the acoustic sources may have on fish. L-DEO and its contractors are committed to applying these measures in order to minimize effects on marine mammals, sea turtles, seabirds, and fish, and other potential environmental impacts. Ultimately, survey operations would be conducted in accordance with Chilean government requirements and all applicable U.S. federal regulations, including IHA and Incidental Take Statement (ITS) requirements.

With the planned monitoring and mitigation measures, unavoidable impacts to each species of marine mammal and sea turtle that could be encountered would be expected to be limited to short-term, localized changes in behavior and distribution near the seismic vessel. At most, effects on marine mammals would be anticipated as falling within the MMPA definition of "Level B Harassment" for those species managed by NMFS; however, NMFS may issue Level A take for some marine mammal species. No long-term or significant effects would be expected on individual marine mammals, sea turtles, seabirds, fish, the populations to which they belong, or their habitats.

LIST OF ACRONYMS

~	approximately
2-D	two-dimensional
3-D	three-dimensional
AEP	Auditory Evoked Potential
AEZ	Artisan Exclusive Zone
AMVER	Automated Mutual-Assistance Vessel Rescue
CA	California
CBD	Convention on Biological Diversity
CITES	Convention on International Trade in Endangered Species
CPPS	Comisión Permanente del Pacífico Sur
dB	decibel
DPS	Distinct Population Segment
EA	Environmental Analysis
EBSA	Environmentally or Biologically Sensitive Marine Area
ENAP	Empresa Nacional del Petróleo
EIS	Environmental Impact Statement
EO	Executive Order
ESA	(U.S.) Endangered Species Act
ETP	Eastern Tropical Pacific
EZ	Exclusion Zone
FAO	Food and Agriculture Organization of the United Nations
FM	Frequency Modulated
FONSI	Finding of no significant impact
GIS	Geographic Information System
GoM	Gulf of Mexico
h	hour
hp	horsepower
Hz	Hertz
IHA	Incidental Harassment Authorization (under MMPA)
in	inch
INACH	Instituto Antártico Chileno (Chilean Antarctic Institute)
IOC	Intergovernmental Oceanographic Commission of UNESCO
IPOC	Integrated Plate Boundary Observatory Chile
IRIS	Incorporated Research Institutions for Seismology
ITS	Incidental Take Statement
IUCN	International Union for the Conservation of Nature
IWC	International Whaling Commission
kHz	kilohertz
km	kilometer
kt	knot
L-DEO	Lamont-Doherty Earth Observatory
LFA	Low-frequency Active (sonar)
LME	Large Marine Ecosystem
m	meter
MBES	Multibeam Echosounder
MCS	Multi-Channel Seismic
MFA	Mid-frequency Active (sonar)
min	minute
MMPA	(U.S.) Marine Mammal Protection Act

MPA	Marine Protected Area
ms	millisecond
MUMPA	Multiple Use Marine and Coastal Protected Area
Mw	Moment magnitude
NMFS	(U.S.) National Marine Fisheries Service
NMSDD	Navy Marine Species Density Database
NOAA	National Oceanic and Atmospheric Administration
NRC	(U.S.) National Research Council
NSF	National Science Foundation
OAWRS	Ocean Acoustic Waveguide Remote Sensing
OBIS	Ocean Biogeographic Information System
OBS	Ocean Bottom Seismometer
OBSIP	Ocean Bottom Seismograph Instrument Pool
OECD	Organisation for Economic Cooperation and Development
OEIS	Overseas Environmental Impact Statement
OOI	Ocean Observatories Initiative
OSU	Oregon State University
p or pk	peak
PEIS	Programmatic Environmental Impact Statement
PI	Principal Investigator
PTS	Permanent Threshold Shift
PSO	Protected Species Observer
rms	root-mean-square
R/V	research vessel
s	second
SAUP	Sea Around Us Project
SBP	Sub-bottom Profiler
SEL	Sound Exposure Level (a measure of acoustic energy)
SIBIMAP-PSE	(Sistema de Información para Biodiversidad Marina y Áreas Protegidas del Pacífico Sudeste)
SIO	Scripps Institution of Oceanography
SOWER	Southern Ocean Whale and Ecosystem Research
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
U.K.	United Kingdom
UNEP	United Nations Environment Programme
U.S.	United States of America
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
UT	University of Texas at Austin
µPa	microPascal
vs.	versus
WCMC	World Conservation Monitoring Centre
y	year

I PURPOSE AND NEED

The purpose of this Draft Environmental Analysis (EA) is to provide the information needed to assess the potential environmental impacts associated with the Proposed Action, including the use of a 36-airgun array during the proposed seismic surveys. This Draft EA was prepared under Executive Order 12114, “Environmental Effects Abroad of Major Federal Actions” (EO 12114). This Draft EA tiers to the Final Programmatic Environmental Impact Statement (PEIS)/Overseas Environmental Impact Statement (OEIS) for Marine Seismic Research funded by the National Science Foundation or Conducted by the U.S. Geological Survey (NSF and USGS 2011) and Record of Decision (NSF 2012), referred to herein as the PEIS. The Draft EA provides details of the Proposed Action at the site-specific level and addresses potential impacts of the proposed seismic surveys on marine mammals, sea turtles, seabirds, fish, and invertebrates. The Draft EA will also be used in support of an application for an Incidental Harassment Authorization (IHA) from the National Marine Fisheries Service (NMFS), and Section 7 consultations under the Endangered Species Act (ESA). The IHA would allow the non-intentional, non-injurious “take by harassment” of small numbers of marine mammals[1] during the proposed seismic surveys by Columbia University’s Lamont-Doherty Earth Observatory (L-DEO) in the southeast Pacific Ocean during ~80 days in 2016/2017. Per NMFS requirement, L-DEO and NSF are also requesting small numbers of Level A takes for the remote possibility of low-level physiological effects; however, because of the characteristics of the Proposed Action and proposed monitoring and mitigation measures, in addition to the general avoidance by marine mammals of loud sounds, Level A takes are considered highly unlikely. On behalf of L-DEO, the U.S. Department of State will seek authorization from Chile for clearance to work within its EEZ and Territorial Waters.

1.1 Mission of NSF

The National Science Foundation (NSF) was established by Congress with the National Science Foundation Act of 1950 (Public Law 810507, as amended) and is the only federal agency dedicated to the support of fundamental research and education in all scientific and engineering disciplines. Further details on the mission of NSF are described in § 1.2 of the PEIS.

1.2 Purpose of and Need for the Proposed Action

As noted in the PEIS, § 1.3, NSF has a continuing need to fund seismic surveys that enable scientists to collect data essential to understanding the complex Earth processes beneath the ocean floor. The seismic surveys being proposed for Chilean waters include: (1) a northern survey to image the region that slipped during the 2014 Pisagua/Iquique earthquake, (2) a central survey to study the area that slipped during the 2015 Illapel earthquake, and (3) a southern survey to examine the deep plate-boundary thrust fault at the south-central Chile margin has produced some of the world’s largest earthquakes and tsunamis (including the largest historic earthquake in 1960, with Mw=9.5, and the 6th largest in 2010, with Mw=8.8). The primary purpose of the ***northern survey*** is to collect seismic data on the continental margin of northern Chile to elucidate geologic controls on a megathrust slip, the 2014 Pisagua/Iquique earthquake sequence, to better understand how geologic structure controlled the initiation, propagation, and termination of this rupture sequence. The main purpose of the ***central survey*** is to specifically

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[1] To be eligible for an IHA under the MMPA, the proposed “taking” (with mitigation measures in place) must not cause serious physical injury or death of marine mammals, must have negligible impacts on the species and stocks, must “take” no more than small numbers of those species or stocks, and must not have an unmitigable adverse impact on the availability of the species or stocks for legitimate subsistence uses.

examine the extent and location of seafloor displacement and related subsurface fault movement of the 2015 Illapel earthquake. The primary goal of the ***southern survey*** is to image the deep plate-boundary thrust fault of the south-central Chile margin to understand plate boundary development and its control on megathrust slip behavior. The proposed activities would collect data in support of research proposals that have been reviewed through the NSF merit review process and have been identified as NSF program priorities to meet NSF's critical need to foster an understanding of Earth processes.

1.3 Background of NSF-funded Marine Seismic Research

The background of NSF-funded marine seismic research is described in § 1.5 of the PEIS.

1.4 Regulatory Setting

The regulatory setting of this EA is described in § 1.8 of the PEIS, including the

- Executive Order 12114;
- Marine Mammal Protection Act (MMPA); and
- Endangered Species Act (ESA).

Additionally, the U.S. Department of State is seeking authorization from Chile for clearance for L-DEO's Research Vessel (R/V) *Marcus G. Langseth* (*Langseth*) to operate in support of the research activity within its EEZ.

II Alternatives Including Proposed Action

In this Draft EA, two alternatives are evaluated: (1) the proposed seismic surveys and associated issuance of an associated IHA and (2) No Action alternative. Additionally, two alternatives were considered but were eliminated from further analysis. A summary of the Proposed Action, the alternative, and alternatives eliminated from further analysis is provided at the end of this section.

2.1 Proposed Action

The project objectives and context, activities, and monitoring/mitigation measures for the proposed seismic surveys are described in the following subsections.

2.1.1 Project Objectives and Context

Researchers from Oregon State University (OSU) and University of Texas at Austin, Institute for Geophysics (UT), propose to conduct seismic surveys using the *Langseth* off Chile in the southeast Pacific Ocean (Fig. 1). The main goal of the ***northern survey*** proposed by OSU is to image the structure of the upper and lower plates in the region that slipped during the 2014 Pisagua/Iquique earthquake sequence and immediately to the south, where an historic seismic gap remains unruptured, in order to better understand how geologic structure controlled the initiation, propagation, and termination of this rupture sequence. This rupture sequence was marked by an unusually long and distinct precursory period that was well recorded by onshore seismic and geodetic instruments deployed as part of the Integrated Plate Boundary Observatory Chile (IPOC). It only ruptured approximately half of a major recognized seismic gap, and rupture stopped at the edge of a large gravity anomaly, suggesting that a change in crustal structure affected slip propagation. As gravity data are not adequate for resolving the structure, seismic tomography and reflection imaging data would be acquired during this project to develop a high-resolution model of upper and lower plate structure in this region.

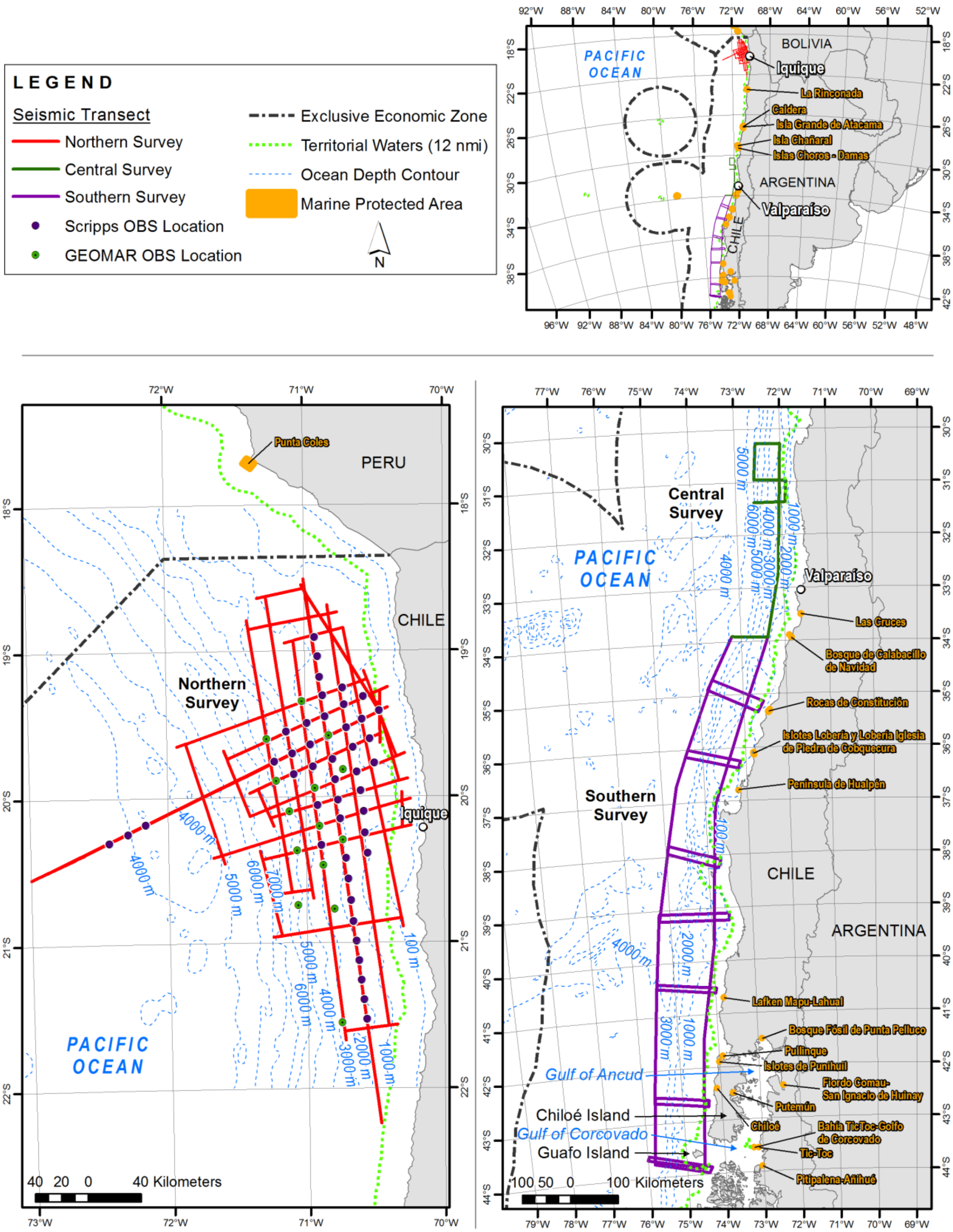


Figure 1. Location of the proposed seismic surveys in the southeast Pacific Ocean during 2016/2017.

The main goal of the ***central survey*** proposed by UT and OSU is to examine the extent and location of seafloor displacement and related subsurface fault movement related to the recent slip during the 16 September 2015 Illapel earthquake. By comparison to existing data acquired prior to this event, these data would provide information on where seafloor displacement occurred, how much displacement there was, and which sub-seafloor faults were mostly likely active during the event. These data are critical for assessing the structures involved in slip, which creates seismic and tsunami hazards that threaten the Chile margin and other locations around the Pacific.

The primary goal of the ***southern survey*** proposed by UT and OSU is to image the deep plate-boundary thrust fault that can produce some of the world's largest earthquakes and tsunamis. The survey is designed to image the characteristics of the plate-boundary thrust, sediment subduction, and upper plate structure within the 2010 Mw 8.8 Maule rupture segment and the 1960 Mw 9.5 Valdivia rupture area. By comparing these structures, it can be determined how the differences in sediment subduction and plate smoothness control the ability of the fault to accumulate strain along the plate interface, and thus control rupture magnitude and earthquake regularity.

To achieve the project goals of the northern survey, the Principal Investigator (PI) Dr. A. Trehu (OSU) proposes to use multi-channel seismic (MCS) surveys and ocean bottom seismometer (OBS) profiles to acquire reflection and refraction data, respectively, on the continental margin of northern Chile. Although not funded through NSF, international collaborators Drs. E. Contreras-Reyes, E. Vera, and D. Comte (Universidad de Chile) and H. Kopp and D. Lange (Research Center for Marine Geosciences, GEOMAR, Helmholtz Centre for Ocean Research) would work with Dr. Trehu to achieve the research goals, providing assistance, such as through logistical support and data acquisition, exchange, and interpretation. For the central and southern surveys, Drs. N. Bangs (UT) and A. Trehu propose to use MCS surveys to acquire data on the continental margin of Chile. International collaborators in the proposed southern survey include Drs. E. Contreras-Reyes and E. Vera.

2.1.2 Proposed Activities

2.1.2.1 Location of the Activities

The proposed survey off northern Chile would occur within the area ~70.2–73.2°W, 18.3–22.4°S, the central proposed survey would occur within ~71.8–73.4°W, 30.1–33.9°S, and the southern proposed survey would occur within ~72.2–76.1°W, 33.9–44.1°S (Fig. 1). Representative survey tracklines are shown in Figure 1; as described further in this document, however, some deviation in actual track lines could be necessary for reasons such as science drivers, poor data quality, inclement weather, or mechanical issues with the research vessel and/or equipment. Water depths in the proposed survey areas range from ~50 to 7600 m. The proposed seismic surveys would be conducted in the southeast Pacific Ocean within the EEZ of Chile; only a small proportion of the surveys would take place in Territorial Waters.

2.1.2.2 Description of Activities

The procedures to be used for the proposed marine geophysical surveys would be similar to those used during previous surveys by L-DEO and would use conventional seismic methodology. The surveys would involve one source vessel, the *Langseth*. The *Langseth* would deploy an array of 36 airguns as an energy source with a total volume of ~6600 in^3. The receiving system would consist of at least 50 OBSs (northern proposed survey) and a single hydrophone streamer 8–15 km in length (all surveys). A longer streamer provides opportunities to suppress unwanted energy that interferes with imaging targets, allows for accurate measurements of seismic velocities, and provides a large amount of data redundancy for enhancing seismic images during data processing. As the airgun array is towed along the survey lines, the OBSs would receive and store the returning acoustic signals internally for later analysis, and the hydrophone streamer would transfer the data to the on-board processing system.

During the northern proposed survey, two two-dimensional (2-D) profiles would be acquired: one, the longest line from southwest to northeast, extending across the source region from the Nazca plate to the coast across the patch of greatest slip during the 2014 earthquake; and the other, the longest north-south line along strike, to image the boundary between the remaining seismic gap and the patch that slipped in 2014. The streamer would be deployed to collect two 2-D profiles with a shot interval of ~25–50 m or ~10–22 s for deep crustal MCS acquisition. The same 2-D profiles would then be acquired with a shot interval of ~300 m or ~2–3 min to the OBSs. Once the long 2-D profiles are completed, the grid of lines (Fig. 1) for three-dimensional (3-D) refraction imaging would be surveyed once for tomography acquisition with a shot interval of ~100–150 m or ~40–60 s. For the central proposed survey, each MCS line of the 2-D survey (Fig. 1) would be surveyed once with a shot interval of ~25 m or ~10 s.

The southern proposed survey would consist of a 2-D MCS reflection survey. First, a margin-parallel, deep-penetration profile would be acquired along the margin to examine the along-strike variation in seismic reflectivity of the subduction thrust and variations in the thickness of sediment subducting into the seismogenic zone. The direction would then be reversed and a series of 7 margin-perpendicular transects (each having 2 or 3 lines) would be acquired, which would cross the outer rise, trench, and slope, and extend onto the shelf. The exact locations of these perpendicular transects may not be as shown in Figure 1, as they would be based on preliminary results from seismic acquisition along the margin-parallel transect along the continental shelf. It would be necessary to go close to the shoreline to image the plate interface as deep into the seismogenic zone as possible. The margin-perpendicular lines would be connected by another margin-parallel line along the outer rise (Fig. 1). Each MCS line (Fig. 1) would be shot once at an interval of ~37.5 m or ~16 s.

A total of ~9630 km of transect lines would be surveyed in the southeast Pacific Ocean: ~4540 km off northern Chile, ~790 km during the central proposed survey, and ~4300 km during the southern proposed survey (Fig. 1). Approximately 9% of line km (mostly during the southern Chile survey) would occur within Territorial Waters. Effort in water <100 m deep would amount to ~3% of the total line km. There could be additional seismic operations associated with turns, airgun testing, and repeat coverage of any areas where initial data quality is sub-standard. In the calculations (see § 4.1.1.5), 25% has been added in the form of operational days which is equivalent to adding 25% to the proposed line km to be surveyed. In addition to the operations of the airgun array, a multibeam echosounder (MBES) and a sub-bottom profiler (SBP) would also be operated from the *Langseth* continuously throughout the surveys. All planned geophysical data acquisition activities would be conducted by L-DEO with on-board assistance by the scientists who have proposed the study. The vessel would be self-contained, and the crew would live aboard the vessel.

Although the proposed project does not have an onshore component for the U.S.-based and NSF-supported participants, previously installed onshore instruments that are part of the IPOC project, as well as a few temporary stations to be deployed by Chilean colleagues to be led by Dr. D. Comte, would record shots during the northern survey. These data would be processed to evaluate regional variations in signal propagation characteristics and identify where there are significant changes in structure that can only be imaged by onshore recording of offshore shots. Onshore data acquired during the proposed northern proposed survey would not be adequate for resolving structure details beneath the coastline, but would provide information for potential planning of onshore projects in future years.

2.1.2.3 Schedule

The surveys off Chile are proposed for 2016/2017. The survey off northern Chile would consist of ~45 days of science operations that include ~28 days of seismic operations, ~13 days of OBS deployment/retrieval, and ~4 days of transit and towed equipment deployment/retrieval. The central Chile survey would involve ~6 days, including ~5 days of seismic operations and ~1 day of equipment deployment/ retrieval time. The southern Chile survey would involve ~32 days of science operations including ~27 days of seismic operations, and ~5 days of transit and towed equipment deployment/retrieval. The *Langseth* would transit to and from the survey locations from either a local port such as Arica, Iquique, or Valparaíso, Chile, or another research survey location in the region.

As the *Langseth* is a national asset, NSF and L-DEO strive to schedule its operations in the most efficient manner possible; schedule efficiencies are achieved when regionally occurring research projects are scheduled consecutively and non-operational transits are minimized. Because of the nature of the NSF merit review process and the long timeline associated with the ESA Section 7 consultation and IHA processes, not all research projects or vessel logistics are identified at the time the consultation documents are submitted to federal regulators; typically, however, these types of details, such as port arrival/departure locations, are not a substantive component of the consultations.

Seasonality of the proposed survey operations does not affect the ensuing analysis (including take estimates), because the best available species densities for any time of the year have been used. It is likely that fewer baleen whales would be encountered in the region during austral summer, as they are typically found at lower latitudes at that time of the year. An exception is the blue whale, which has been shown to occur in feeding aggregations in the southern portion of the southern proposed survey area during the austral summer, particularly February–April; this has been taken into account in the take estimates.

2.1.2.4 Vessel Specifications

The *Langseth* is described in § 2.2.2.1 of the PEIS. The vessel speed during all seismic operations would be ~4.5 kt (~8.3 km/h).

2.1.2.5 Airgun Description

During the proposed surveys, the *Langseth* full array, consisting of four strings with 36 airguns (plus 4 spares) and a total volume of ~6600 in^3, would be used. The airgun arrays are described in § 2.2.3.1 of the PEIS, and the airgun configurations are illustrated in Figures 2-11 to 2-13 of the PEIS. The 4-string array would be towed at a depth of 9–12 m during the northern proposed survey; the central and southern proposed surveys would use a tow depth of 9 m. The shot intervals would range from 25–50 m for MCS acquisition, 100–150 m for simultaneous MCS and tomography acquisition, and 300 m for tomography acquisition.

2.1.2.6 OBS Description and Deployment

During the northern proposed survey, the *Langseth* would deploy ~50 OBSs provided by the Ocean Bottom Seismograph Instrument Pool (OBSIP), which is run by Incorporated Research Institutions for Seismology (IRIS). Nominal OBS spacing would be 15 km. Once all OBSs are deployed, seismic acquisition would commence. Depending on factors such as weather conditions, all OBSs could be recovered at the end of the survey or partial OBS recovery and seismic acquisition could alternate. The OBSs that would be used during the northern proposed survey are from Scripps Institution of Oceanography (SIO). The SIO L-Cheapo OBSs have a height of ~1 m and a maximum diameter of ~1 m. The anchors are 36-kg iron grates with dimensions 7 × 91 × 91.5 cm.

The OBS sites depicted on Figure 1 are representative of the desired configuration for the proposed survey; final sites, however, would be determined after further review of the swath bathymetric data acquired by GEOMAR in this region and geologic conditions assessed during the actual survey, as some sites may be deemed unsuitable to achieve the research goals. Most sites are located in water depths <5500 m, where OBSs would be coupled to an anchor on the seafloor. However, some OBS sites could be in water >6000 m deep, where the OBS would be tethered to an anchor on the seafloor and float within the water column at a depth of ~5500 m.

Fourteen additional OBSs funded and deployed by GEOMAR in the region in early December 2015 would be recovered by the *Langseth* during the proposed survey. Another four GEOMAR OBSs could be deployed by the *Langseth* in water >6000 m deep at ~19.8–20.0 °S, 71.3–71.7°W (eliminating the need to tether any SIO OBSs to an anchor), but it is uncertain at the time of writing whether these instruments are available for this project. Once an OBS is ready to be retrieved, an acoustic release transponder interrogates the instrument at a frequency of 8–11 kHz, and a response is received at a frequency of 11.5–13 kHz. The burn-wire release assembly is then activated, and the instrument is released from the anchor to float to the surface. For tethered OBSs, the tether is also recovered.

2.1.2.7 Additional Acoustical Data Acquisition Systems

Along with the airgun operations, two additional acoustical data acquisition systems would be operated from the *Langseth* during the proposed surveys, an MBES and SBP. The ocean floor would be mapped with the Kongsberg EM 122 MBES and a Knudsen Chirp 3260 SBP. These sources are described in § 2.2.3.1 of the PEIS.

2.1.2.6 Additional Equipment

A Liquid Robotics SV2 Wave Glider could be used during the proposed surveys for a period of several hours to collect data from seafloor sensors. The Wave Glider is an autonomous marine vehicle that consists of a small sub with sensors that is suspended from a float or platform at the water surface. It is remotely piloted and wave propelled. An integrated acoustic transceiver communicates from the platform to a subsea-mounted acoustic data logger (ADL); the ADL then transfers data to a station on the platform which transmits them to a control center via satellite. The SV2 Wave Glider platform is 2.1 m long and 60 cm wide.

The SV2 Wave Glider would be used and operated in a manner and environment similar to other general types of gliders used for oceanographic research. General descriptions, environmental analysis, and conclusions of glider use can be found in the environmental documentation for the NSF Ocean Observatories Initiative (OOI; which can be found at http://www.nsf.gov/geo/oce/envcomp/) including the Site-Specific Environmental Assessment for the National Science Foundation-Funded Ocean Observatories Initiative (2011), Final Programmatic Environmental Assessment For NSF-Funded OOI (2008), Supplemental Environmental Reports (2008, 2009, 2013, and 2015), and associated Finding of No Significant Impacts or FONSI (2009 and 2011), and are incorporated by reference as if fully set forth herein. As documented and concluded in the NSF OOI EAs and FONSIs, no significant impacts were anticipated from the use of gliders; similarly, no environmental impacts would be anticipated from use of the SV2 Wave Glider during the survey, and it is therefore not discussed further in this anaylsis.

2.1.3 Monitoring and Mitigation Measures

Standard monitoring and mitigation measures for seismic surveys are described in § 2.4.1.1 and 2.4.2 of the PEIS and are described to occur in two phases: pre-cruise planning and operations. The following sections describe the efforts during both stages for the proposed activities.

2.1.3.1 Planning Phase

As discussed in § 2.4.1.1 of the PEIS, mitigation of potential impacts from the proposed activities begin during the planning phase. Several factors were considered during the planning phase of the proposed activities, including

***Energy Source*.—**Part of the considerations for the proposed marine seismic surveys was to evaluate whether the research objectives could be met with a smaller energy source than the full 36-airgun, 6600-in^3 Langseth array. It was decided that the scientific objectives for the proposed surveys could not be met using a smaller source as it would not produce enough low-frequency energy with a consistent pulse shape at the interval needed to achieve the necessary propagation distances. Additionally, a large airgun array would assure sufficiently strong signal return from targets, which are as deep as ~15 km.

***Survey Timing*.—**The PIs are working with L-DEO and NSF to identify potential times to carry out the proposed surveys taking into consideration key factors such as environmental conditions (i.e., the seasonal presence of marine mammals, sea turtles, and seabirds), weather conditions, equipment, and optimal timing for other proposed seismic surveys using the *Langseth*. Most marine mammal species are expected to occur in the area year-round, but some migratory baleen whales occur in the area on a seasonal basis. It is likely that fewer baleen whales would occur in the region during austral summer, as they typically occur in lower latitudes at that time. An exception is the blue whale, which has been shown to occur in feeding aggregations in the southern portion of the southern proposed survey area during February–April.

***Mitigation Zones*.—**During the planning phase, mitigation zones for the proposed marine seismic surveys were calculated based on modeling by L-DEO for both the exclusion and safety zones. Received sound levels have been predicted by L-DEO's model (Diebold et al. 2010, provided as Appendix H in the PEIS), as a function of distance from the airguns, for the 36-airgun array at various tow depths and for a single 1900LL 40-in^3 airgun, which would be used during power downs. This modeling approach uses ray tracing for the direct wave traveling from the array to the receiver and its associated source ghost (reflection at the air-water interface in the vicinity of the array), in a constant-velocity half-space (infinite homogeneous ocean layer, unbounded by a seafloor). In addition, propagation measurements of pulses from the 36-airgun array at a tow depth of 6 m have been reported in deep water (~1600 m), intermediate water depth on the slope (~600–1100 m), and shallow water (~50 m) in the Gulf of Mexico (GoM) in 2007–2008 (Tolstoy et al. 2009; Diebold et al. 2010).

For deep and intermediate-water cases, the field measurements cannot be used readily to derive mitigation radii, as at those sites the calibration hydrophone was located at a roughly constant depth of 350–500 m, which may not intersect all the sound pressure level (SPL) isopleths at their widest point from the sea surface down to the maximum relevant water depth for marine mammals of ~2000 m. Figures 2 and 3 in Appendix H of the PEIS show how the values along the maximum SPL line that connects the points where the isopleths attain their maximum width (providing the maximum distance associated with each sound level) may differ from values obtained along a constant depth line. At short ranges, where the direct arrivals dominate and the effects of seafloor interactions are minimal, the data recorded at the deep and slope sites are suitable for comparison with modeled levels at the depth of the calibration hydrophone. At longer ranges, the comparison with the mitigation model—constructed from the maximum SPL through the entire water column at varying distances from the airgun array—is the most relevant. The results are summarized below.

In deep and intermediate water depths, comparisons at short ranges between sound levels for direct arrivals recorded by the calibration hydrophone and model results for the same array tow depth are in good agreement (Fig. 12 and 14 in Appendix H of the PEIS). Consequently, isopleths falling within this domain can be predicted reliably by the L-DEO model, although they may be imperfectly sampled by measurements recorded at a single depth. At greater distances, the calibration data show that seafloor-reflected and sub-seafloor-refracted arrivals dominate, whereas the direct arrivals become weak and/or incoherent (Fig. 11, 12, and 16 in Appendix H of the PEIS). Aside from local topography effects, the region around the critical distance (~5 km in Fig. 11 and 12, and ~4 km in Fig. 16 in Appendix H of the PEIS) is where the observed levels rise closest to the mitigation model curve. However, the observed sound levels are found to fall almost entirely below the mitigation model curve (Fig. 11, 12, and 16 in Appendix H of the PEIS). Thus, analysis of the GoM calibration measurements demonstrates that although simple, the L-DEO model is a robust tool for conservatively estimating mitigation radii. In shallow water (<100 m), the depth of the calibration hydrophone (18 m) used during the GoM calibration survey was appropriate to sample the maximum sound level in the water column, and the field measurements reported in Table 1 of Tolstoy et al. (2009) for the 36-airgun array at a tow depth of 6 m can be used to derive mitigation radii.

The proposed surveys would acquire data with the 36-airgun array at tow depths of 9 and 12 m. For deep water (>1000 m), we use the deep-water radii obtained from L-DEO model results down to a maximum water depth of 2000 m (Fig. 2 and 3). The radii for intermediate water depths (100–1000 m) are derived from the deep-water ones by applying a correction factor (multiplication) of 1.5, such that observed levels at very near offsets fall below the corrected mitigation curve (Fig. 16 in Appendix H of the PEIS). The shallow-water radii are obtained by scaling the empirically derived measurements from the GoM calibration survey to account for the differences in tow depth between the calibration survey (6 m) and the proposed surveys (9 and 12 m); whereas the shallow water GOM may not exactly replicate the shallow water environment at the proposed survey sites, it has been shown to serve as a good and very conservative proxy (Crone et al. 2014). A simple scaling factor is calculated from the ratios of the isopleths calculated by the deep-water L-DEO model, which are essentially a measure of the energy radiated by the source array: the 150-decibel (dB) Sound Exposure Level (SEL)[2] corresponds to deep-water maximum radii of 9334 m and 11,250 m for 9 and 12-m tow depths, respectively (Fig. 2 and 3), and 7244 m for a 6-m tow depth (Fig. 4), yielding scaling factors of 1.29 and 1.55 to be applied to the shallow-water 6-m tow depth results. Similarly, the 170 dB SEL corresponds to deep-water maximum radii of 927 and 1117 m for 9 and 12-m tow depths (Fig. 2) and 719 m for 6-m tow depth (Fig. 4), yielding the same 1.29 and 1.55 scaling factors. Measured 160-, 180-, and 190-dB re 1µPa$_{rms}$ distances in shallow water for the 36-airgun array towed at 6 m depth were 17.5 km, 1.6 km, and 458 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by 1.29 to account for the tow depth difference between 6 and 9 m yields distances of 22.58 km, 2.06 km, and 591 m, respectively.

[2] SEL (measured in dB re 1 µPa$^2 \cdot$ s) is a measure of the received energy in the pulse and represents the SPL that would be measured if the pulse energy were spread evenly across a 1-s period. Because actual seismic pulses are less than 1 s in duration in most situations, this means that the SEL value for a given pulse is usually lower than the SPL calculated for the actual duration of the pulse. In this EA, we assume that rms pressure levels of received seismic pulses would be 10 dB higher than the SEL values predicted by L-DEO's model.

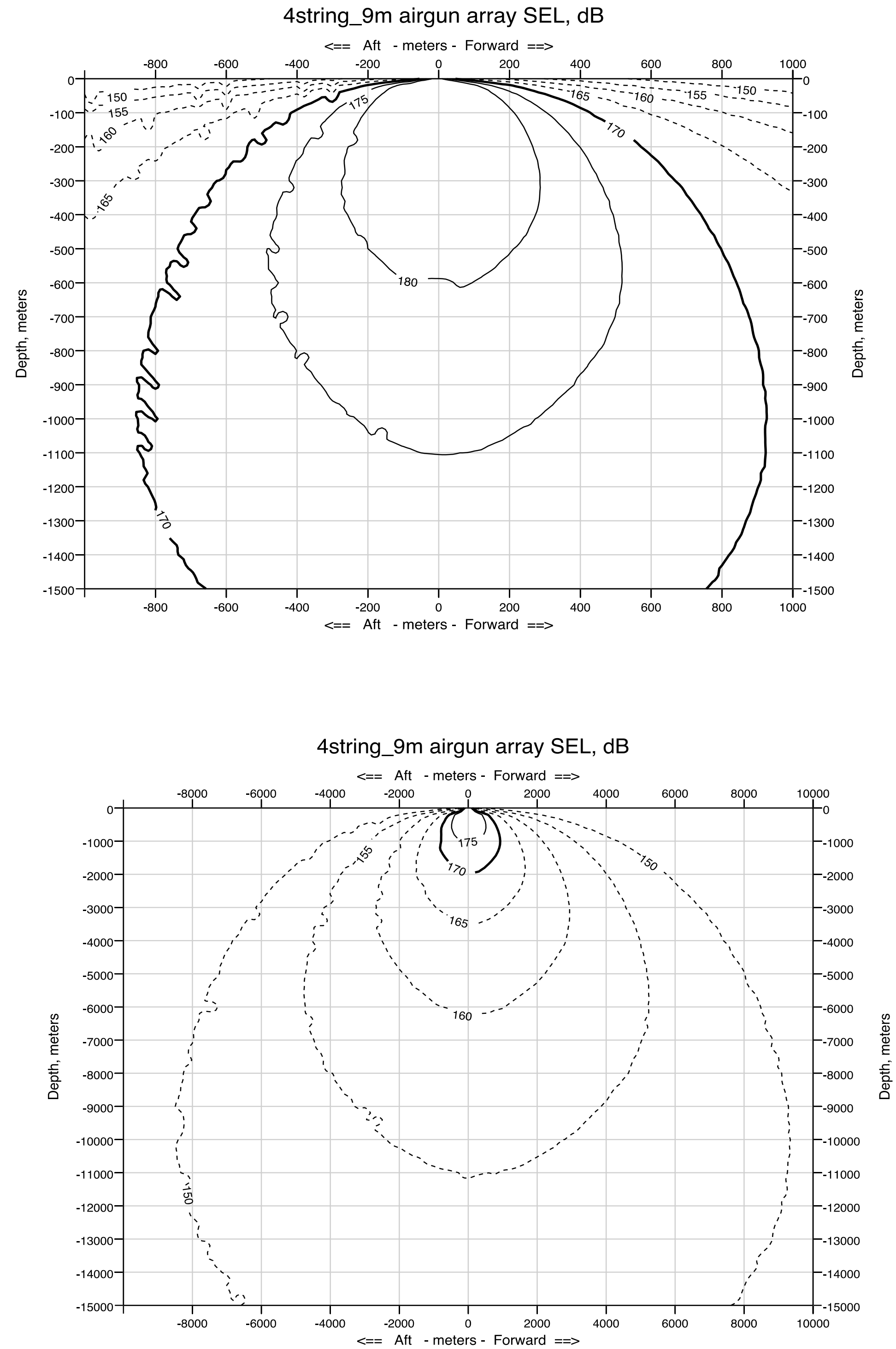


FIGURE 2. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array planned for use during the proposed surveys in the southeast Pacific Ocean at a 9-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

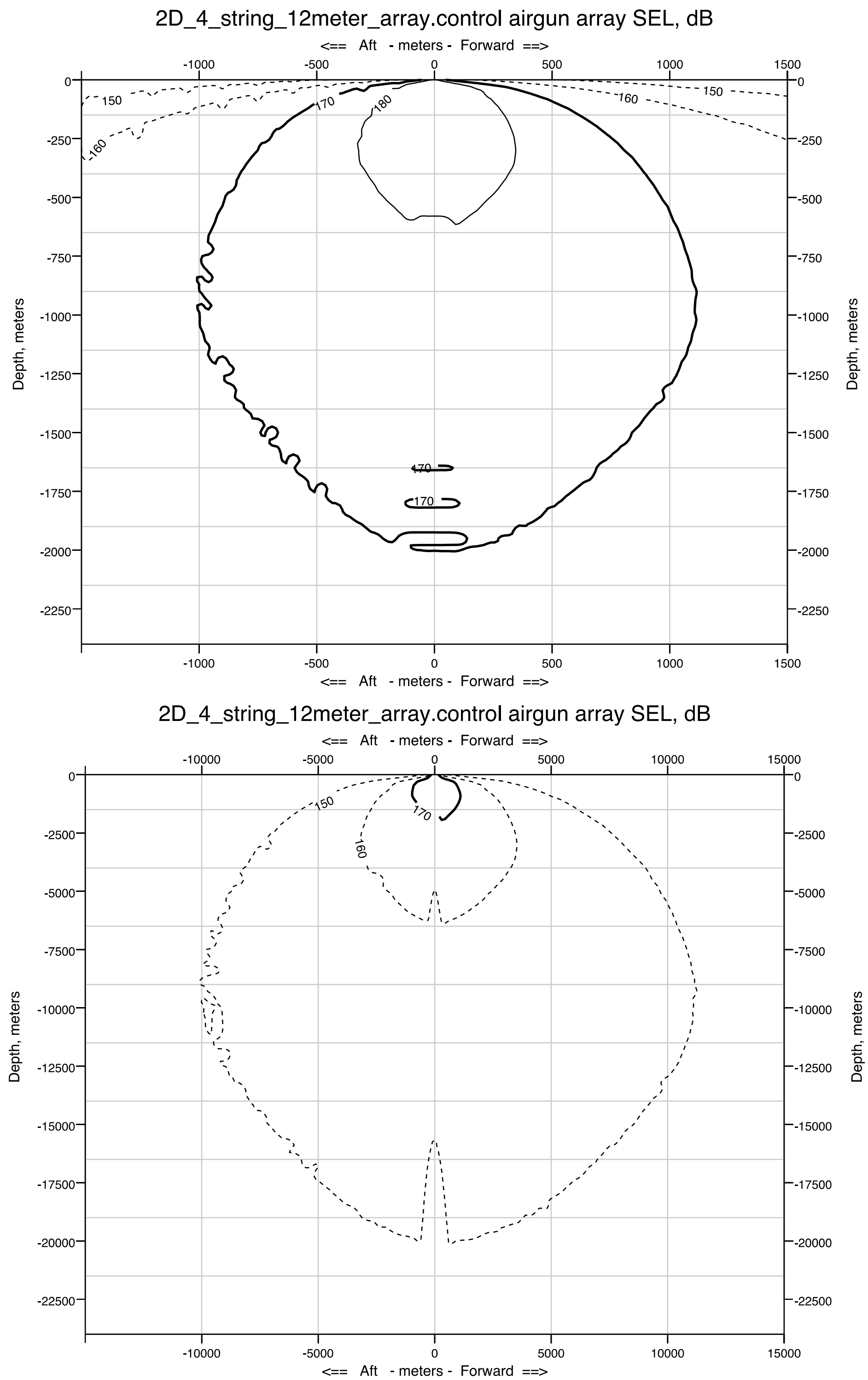
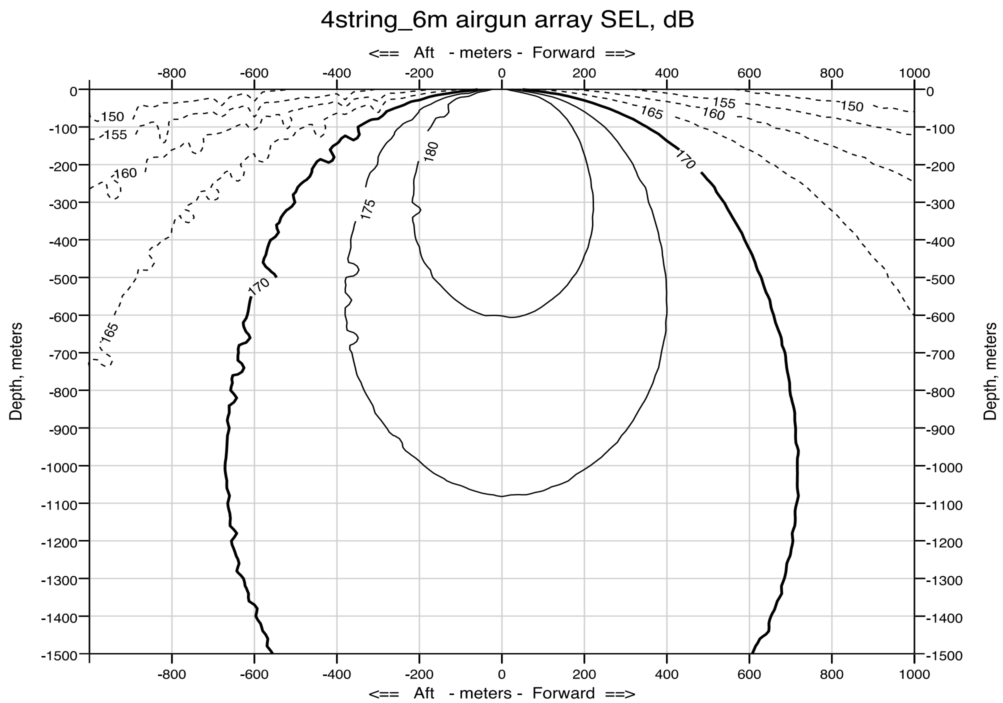


FIGURE 3. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array planned for use during the proposed surveys in the southeast Pacific Ocean at a 12-m tow depth. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.



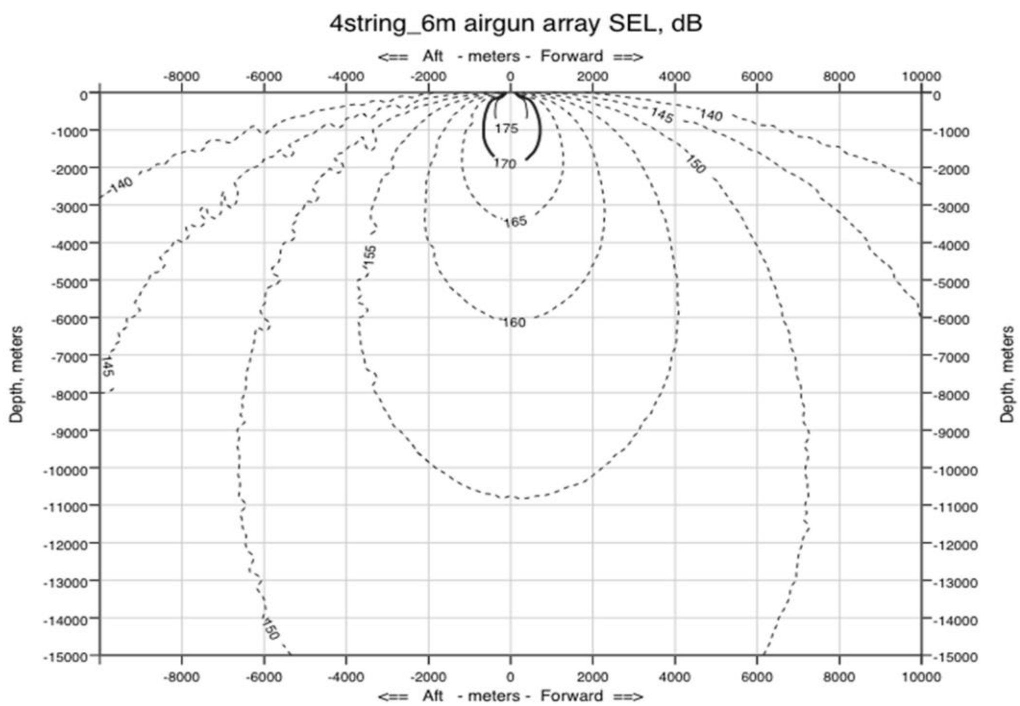


FIGURE 4. Modeled deep-water received sound exposure levels (SELs) from the 36-airgun array at a 6-m tow depth used during the GoM calibration survey. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170 dB SEL isopleth as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

Multiplying by 1.55 to account for the tow depth difference between 6 and 12 m yields distances of 27.13 km, 2.48 km, and 710 m, respectively.

Measurements have not been reported for the single 40-in^3 airgun. The 40-in^3 airgun fits under the low-energy source category in the PEIS. In § 2.4.2 of the PEIS, Alternative B (the Preferred Alternative) conservatively applies an exclusion zone (EZ) of 100 m for all low-energy acoustic sources in water depths >100 m. The L-DEO model is adopted here for the single Bolt 1900LL 40-in^3 airgun that would be used during power downs. L-DEO model results are used to determine the 160-dB$_{rms}$ radius for the 40-in^3 airgun at 12-m tow depth in deep water (Fig. 5).

For intermediate-water depths, a correction factor of 1.5 was applied to the deep-water model results. For shallow water, a scaling of the field measurements obtained for the 36-airgun array was used: the 150-dB SEL level corresponds to a deep-water radius of 431 m for the 40-in^3 airgun at 12-m tow depth (Fig. 4) and 7244 for the 36-airgun array at 6-m tow depth (Fig. 2), yielding a scaling factor of 0.0595. Similarly, the 170-dB SEL level corresponds to a deep-water radius of 43 m for the 40-in^3 airgun at 12-m tow depth (Fig. 4) and 719 m for the 36-gun array at 6-m tow depth (Fig. 2), yielding a scaling factor of 0.0598. Measured 160-, 180-, and 190-dB re 1µPa$_{rms}$ distances in shallow water for the 36-airgun array towed at 6-m depth were 17.5 km, 1.6 km, and 458 m, respectively, based on a 95th percentile fit (Tolstoy et al. 2009). Multiplying by 0.0595 and 0.0598 to account for the difference in array sizes and tow depths yields distances of 1041 m, 96 m, and 27 m, respectively.

Table 1 shows the distances at which the 160-, 180-, and 190-dB re 1µPa$_{rms}$ sound levels are expected to be received for the 36-airgun array and the single (mitigation) airgun. The 180- and 190-dB re 1 µPa$_{rms}$ distances are the safety criteria as specified by NMFS (2000) for cetaceans and pinnipeds, respectively. The 180-dB distance would also be used as the EZ for sea turtles, as required by NMFS in most other recent seismic projects per the IHAs. Enforcement of mitigation zones via power and shut downs would be implemented in the Operational Phase. The 160-dB level is the behavioral disturbance criterion that is used to estimate anticipated takes for marine mammals; a 166-dB level is used to determine behavioral disturbance for sea turtles.

A recent retrospective analysis of acoustic propagation of *Langseth* sources in a coastal/shelf environment from the Cascadia Margin off Washington suggests that predicted (modeled) radii (using an approach similar to that used here) for *Langseth* sources were 2–3 times larger than measured in shallow water, so in fact, as expected, were very conservative (Crone et al. 2014). Similarly, preliminary analysis by Crone (2015, L-DEO, pers. comm.) of data collected during a survey off New Jersey in 2014 and 2015 confirmed that *in situ* measurements and estimates of the 160- and 180-dB distances collected by the *Langseth* hydrophone streamer were similarly 2–3 times smaller than the predicted operational mitigation radii. In fact, five separate comparisons conducted of the L-DEO model with *in situ* received levels[3] have confirmed that the L-DEO model generated conservative exclusion zones, resulting in significantly larger EZs than necessary.

Southall et al. (2007) made detailed recommendations for new science-based noise exposure criteria. In July 2015, NOAA published a revised version of its 2013 draft guidance for assessing the effects of anthropogenic sound on marine mammals (NOAA 2015). At the time of preparation of this

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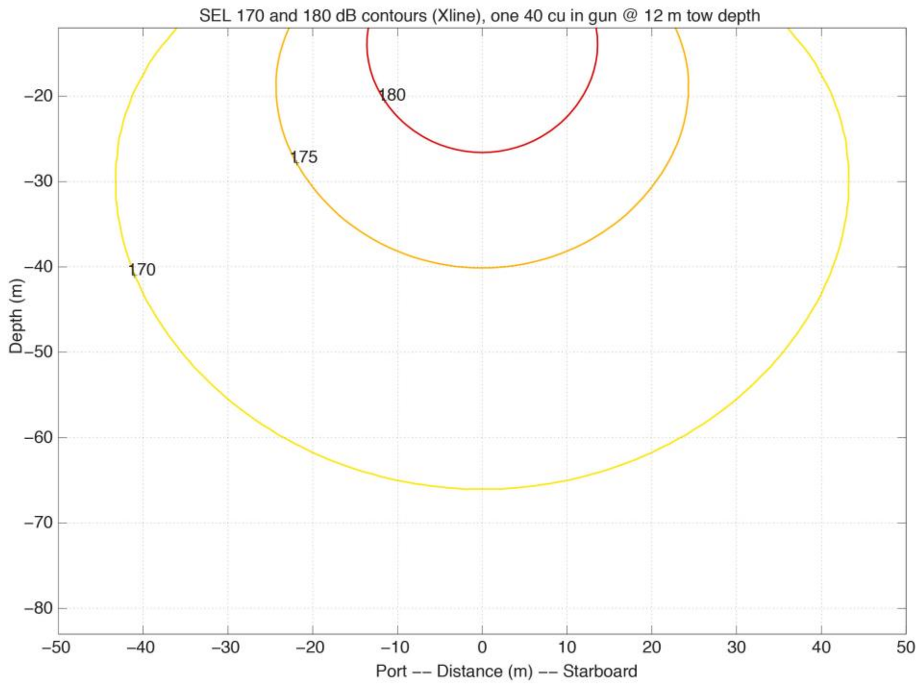
[3] L-DEO surveys off the Yucatán Peninsula in 2004 (Barton et al. 2006; Diebold et al. 2006), in the Gulf of Mexico in 2008 (Tolstoy et al. 2009; Diebold et al. 2010), off Washington and Oregon in 2012 (Crone et al. 2014), and off New Jersey in 2014 and 2015 (Crone 2015, L-DEO, pers. comm.)



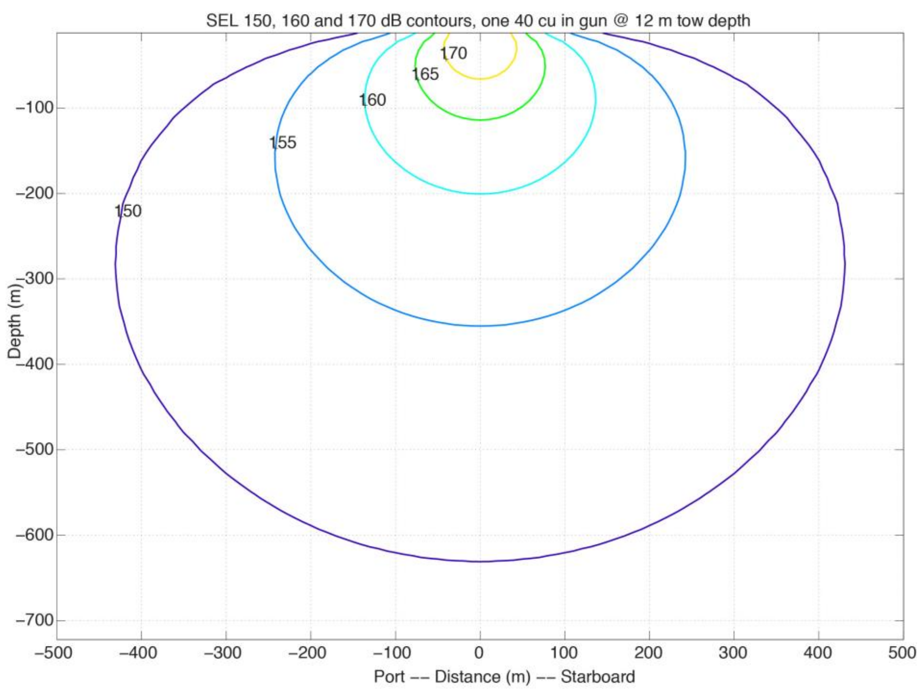


FIGURE 5. Modeled deep-water received sound exposure levels (SELs) from a single 40-in^3 airgun towed at 12 m depth, which is planned for use as a mitigation gun during the proposed surveys in the southeast Pacific Ocean. Received rms levels (SPLs) are expected to be ~10 dB higher. The plot at the top provides the radius to the 170-dB SEL isopleths as a proxy for the 180-dB rms isopleth, and the plot at the bottom provides the radius to the 150-dB SEL isopleth as a proxy for the 160-dB rms isopleth.

TABLE 1. Predicted distances to which sound levels ≥190-, 180-, 166-, and 160-dB re 1 μPa_{rms} are expected to be received during the proposed surveys in the Southeast Pacific Ocean. For the single mitigation airgun, the EZ is the conservative EZ for all low-energy acoustic sources defined in the PEIS for water depths >100 m and the modeled level for water depths <100 m[5].

Source and Volume	Tow Depth (m)	Water Depth (m)[1]	Predicted rms Radii (m)			
			190 dB	180 dB	166 dB	160 dB
Single Bolt airgun, 40 in^3	9 or 12	>1000 m	100	100	185[2]	431[2]
		100–1000 m	100	100	324[3]	647[3]
		<100 m	27[4]	96[4]	501[4]	1041[4]
4 strings, 36 airguns, 6600 in^3	9	>1000 m	286[2]	927[2]	3740[2]	5780[2]
		100–1000 m	429[3]	1391[3]	5610[3]	8670[3]
		<100 m	591[4]	2060[4]	10,862[4]	22,580[4]
4 strings, 36 airguns, 6600 in^3	12	>1000 m	348[2]	1116[2]	4411[2]	6908[2]
		100–1000 m	522[3]	1674[3]	6617[3]	10,362[3]
		<100 m	710[4]	2480[4]	12,630[4]	27,130[4]

[1] Very few line kilometers (~25 km and 238 km) are planned for water <100 m deep during the northern and southern proposed surveys, respectively.
[2] Distance is based on L-DEO model results.
[3] Distance is based on L-DEO model results with a 1.5 x correction factor between deep and intermediate water depths.
[4] Distance is based on empirically derived measurements in the GoM with scaling applied to account for differences in tow depth.
[3] Modeled distances based on empirically derived measurements in the GoM are smaller.

Draft EA, the content of the final guidelines and how they would be implemented are uncertain. As such, this Draft EA has been prepared in accordance with the current NOAA acoustic practices, and the procedures are based on best practices noted by Pierson et al. (1998), Weir and Dolman (2007), Nowacek et al. (2013), Wright (2014), and Wright and Cosentino (2015).

Enforcement of mitigation zones via power and shut downs would be implemented in the Operational Phase.

2.1.3.2 Operational Phase

Marine mammals and sea turtles are known to occur in the proposed survey areas. However, the number of individual animals expected to be approached closely during the proposed activities would be relatively small in relation to regional population sizes. To minimize the likelihood that potential impacts could occur to the species and stocks, monitoring and mitigation measures proposed during the operational phase of the proposed activities, which are consistent with the PEIS and past IHA and incidental take statement (ITS) requirements, include

1. monitoring by protected species observers (PSOs) for marine mammals, sea turtles, and ESA-listed seabirds diving near the vessel, and observing for potential impacts of acoustic sources on fish;
2. passive acoustic monitoring (PAM);
3. PSO data and documentation; and

4. mitigation during operations (speed or course alteration; power-down, shut-down, and ramp-up procedures; and special mitigation measures for rare species, species concentrations, and sensitive habitats).

Five independently contracted PSOs would be on board the survey vessel with rotating shifts to allow two observers to monitor for marine species during daylight hours, and one observer to conduct PAM during day- and night-time seismic operations. The proposed operational mitigation measures are standard for all high-energy seismic cruises, per the PEIS and are described in the IHA application, and therefore are not discussed further here. Special mitigation measures were considered for these cruises. It is unlikely that concentrations of large whales within the 160-dB isopleth would be encountered, but if so, they would be avoided.

With the proposed monitoring and mitigation provisions, potential effects on most if not all individuals would be expected to be limited to minor behavioral disturbance. Those potential effects would be expected to have negligible impacts both on individual marine mammals and on the associated species and stocks. Ultimately, survey operations would be conducted in accordance with all applicable U.S. federal regulations, including IHA and ITS requirements, on the high seas and outside of Chilean Territorial Waters, and in accordance with any Chilean governmental requirements throughout the proposed survey areas.

2.2 Alternative 1: No Action Alternative

An alternative to conducting the Proposed Action is the "No Action" alternative, i.e., do not issue an IHA and do not conduct the research operations (Table 2). If the research was not conducted, the "No Action" alternative would result in no disturbance to marine mammals attributable to the Proposed Action. Although the No-Action Alternative is not considered a reasonable alternative because it does not meet the purpose and need for the Proposed Action, it is included and carried forward for analysis in § 4.3.

2.3 Alternatives Considered but Eliminated from Further Analysis

Table 2 provides a summary of the Proposed Action, alternative, and alternatives eliminated from further analysis.

2.3.1 Alternative E1: Alternative Location

The goal of the proposed research is to elucidate geologic controls on megathrust slips, including the 2014 Pisagua/Iquique and 2015 Illapel earthquakes, and to improve our understanding of the slip and tsunami generation processes. The proposed survey locations and designs have been specifically selected to focus on the unique features of recent large earthquakes and the 1960 Valdivia earthquake. Previously acquired seismic images show that large volumes of sediment are subducted along parts of the margin, and this is an excellent location to test the possibility of smoothing of the plate interface and strong coupling between plates. However, most important, there is nowhere else in the world where there is a strong along-strike variation in trench sediment thickness where the effects of thick to thin sediment subduction on earthquake behavior can be examined.

The northern proposed survey takes advantage of the correlation between gravity anomalies indicative of variations in crustal structure and an exceptionally well-documented slip history of a complex sequence of earthquakes. This combination of factors is not available elsewhere. In addition, the location of the proposed northern proposed survey is linked to the IPOC program, which although primarily an onshore activity, recently initiated an offshore natural source seismic and geodetic component that would enhance the proposed survey. Locations other than these particular segments of

TABLE 2. Summary of Proposed Action, Alternative Considered, and Alternatives Eliminated

Proposed Action	Description
Proposed Action: Conduct marine geophysical surveys and associated activities in the Southeast Pacific Ocean	Under this action, 2-D profiles and a 3-D grid seismic survey are proposed. When considering transit; equipment deployment, maintenance, and retrieval; weather; marine mammal activity; and other contingencies, the proposed activities would be expected to be completed in ~80 days. The affected environment, environmental consequences, and cumulative impacts of the proposed activities are described in § III and IV. The standard monitoring and mitigation measures identified in the NSF PEIS would apply, along with any additional requirements identified by regulating agencies. All necessary permits and authorizations, including an IHA, would be requested from regulatory bodies.
Alternatives	Description
Alternative 1: No Action	Under this Alternative, no proposed activities would be conducted and seismic data would not be collected. Whereas this alternative would avoid impacts to marine resources, it would not meet the purpose and need for the Proposed Action. Geological data of scientific value and relevance increasing our understanding of the geologic controls on megathrust slips and understanding of the slip and tsunami generation processes would not be collected. The collection of new data, interpretation of these data, and introduction of new results into the greater scientific community and applicability of these data to other similar settings would not be achieved. No permits and authorizations, including an IHA, would be needed from regulatory bodies, as the Proposed Action would not be conducted.
Alternatives Eliminated from Further Analysis	Description
Alternative E1: Alternative Location	The proposed survey locations have been specifically selected to image the regions of the 2014 Pisagua/Iquique and 2015 Illapel earthquakes to better understand slip and tsunami generation processes. The proposed science underwent the NSF merit review process, and the science, including the site location, was determined to be meritorious.
Alternative E2: Use of Alternative Technologies	Under this alternative, L-DEO would use alternative survey techniques, such as marine vibroseis, that could potentially reduce impacts on the marine environment. Alternative technologies were evaluated in the PEIS, § 2.6. At this time, however, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need.

the Chilean margin would therefore not meet the necessary research conditions or research goals. Although the sites occur within Ecologically or Biologically Sensitive Areas (EBSAs) as defined under the Convention on Biological Diversity, there is currently no other methodology, or ability to change the proposed survey site locations, to study recent and past megathrust slips, the critical objective of the proposed research.

2.3.2 Alternative E2: Use of Alternative Technologies

As described in § 2.6 of the PEIS, alternative technologies to the use of airguns were investigated to conduct high-energy seismic surveys. At this time, these technologies are still not feasible, commercially viable, or appropriate to meet the Purpose and Need. Additional details about these technologies are given in the Final USGS EA (RPS 2014a).

III AFFECTED ENVIRONMENT

As described in the PEIS, Chapter 3, the description of the affected environment focuses only on those resources potentially subject to impacts. Accordingly, the discussion of the affected environment (and associated analyses) has focused mainly on those related to marine biological resources, as the proposed short-term activity has the potential to impact marine biological resources within the Project areas. These resources are identified in § III, and the potential impacts to these resources are discussed in § IV. Initial review and analysis of the proposed Project activity determined that the following resource areas did not require further analysis in this EA:

- *Air Quality/Greenhouse Gases*—Project vessel emissions would result from the proposed activity; however, these short-term emissions would not result in any exceedance of Federal Clean Air standards. Emissions would be expected to have a negligible impact on the air quality within the proposed survey areas;
- *Land Use*—All activities are proposed to occur in the marine environment. Therefore, no changes to current land uses or activities in the Project area would result from the proposed Project;
- *Safety and Hazardous Materials and Management*—No hazardous materials would be generated or used during the proposed activity. All Project-related wastes would be disposed of in accordance with Federal and international requirements;
- *Geological Resources (Topography, Geology and Soil)*—The proposed Project would result in very minor disturbance to seafloor sediments from OBS deployments; small anchors would not be recovered. The proposed activity would, therefore, not adversely affect geologic resources;
- *Water Resources*—No discharges to the marine environment that would adversely affect marine water quality are expected in the Project area. Therefore, there would be no impacts to water resources resulting from the proposed Project activity;
- *Terrestrial Biological Resources*—All proposed Project activities would occur in the marine environment and would not impact terrestrial biological resources;
- *Visual Resources*—No visual resources would be expected to be negatively impacted as the area of operation is outside of the land and coastal viewshed;
- *Socioeconomic and Environmental Justice*—Implementation of the proposed Project would not affect, beneficially or adversely, socioeconomic resources, environmental justice, or the protection of children. No changes in the population or additional need for housing or schools would occur. Because of the location of the proposed activity and distance form shore, human activities in the area around the survey vessel would be limited to recreational diving, fishing activities, and other vessel traffic. Diving, fishing, vessel traffic, and potential impacts are described in further detail in § III and IV. No other socioeconomic impacts would be expected as result of the proposed activity; and
- *Cultural Resources*—There are no known cultural resources in the proposed Project area; therefore, no impacts to cultural resources would be expected.

3.1 Physical Environment and Oceanography

The mainland EEZ of Chile encompasses ~2 million km^2. In addition, several oceanic islands are part of the Chilean EEZ: the Desventuradas Islands, 850 km from the coast; the Juan Fernández, Felix, and Ambrosio Islands, 890 km from the coast; and Easter Island, >3500 km from the mainland (van der Meer et al. 2015). In the southeast Pacific Ocean, wind patterns are influenced by the southeast Pacific subtropical anticyclone that creates Equatorward, upwelling-favorable winds (Thiel et al. 2007). These winds are considered rather constant throughout the year north of 26°S (Figueroa 2002 *in* Thiel et al. 2007).

The Chilean Sea is considered among the most productive marine ecosystems in the world as well as the largest upwelling system. Strong coastal winds drive water northward and off the coast, resulting in upwelling of deeper nutrient-rich waters that encourages strong primary production which in turn results in greater biomass of zooplankton for fish and invertebrates to feed on (Carr and Kearns 2003). The main influence on the proposed survey areas off the coast of Chile is the Humboldt upwelling system (Thiel et al. 2007). The Humboldt Current Large Marine Ecosystem (LME) extends along the west coast of South America from northern Peru to the southern tip of Chile (McGinley 2008). It has a surface area of 2.5 million km^2, containing 0.42% of the world's seamounts and 24 major estuaries (Heileman et al. 2008 *in* Miloslavich et al. 2011). The Humboldt Current LME is one of the major upwelling systems of the world, with moderate to extremely high primary productivity (150–300 gC/m^2/y) and highly productive fisheries (Miloslavich et al. 2011). It is characterized by cold waters flowing toward the Equator, with offshore Ekman transport and coastal upwelling of cold, nutrient-rich subsurface water (Thiel et al. 2007). The system can export water up to 1000 km offshore (McGinley 2008).

The Chilean marine ecosystem pelagic territory is made up of three regions: the northern upwelling (18–30ºS), central/southern upwelling (30–42ºS), and austral fjords (42–55ºS) regions (Escribano et al. 2003). Upwelling occurs in the northern region year-round, but is more seasonal in the central/southern region (Thiel et al. 2007). In the northern upwelling region, most of the biological production takes place near the coast, in association with a narrow (<10 km) continental shelf (Escribano et al. 2003; Thiel et al. 2007). The shelf is much wider (up to ~40 km) in the central region, and upwelling is stronger in the spring and summer (Escribano et al. 2003). The northern and central regions are also subject to high environmental variability caused by the ENSO (El Niño Southern Oscillation and LNSO (La Niña Southern Oscillation), which cause important changes in species community composition and abundance (Thiel et al. 2007; Miloslavich et al. 2011). The northern, central, and southern Chile Humboldt upwelling regions are also identified as EBSAs under the Convention on Biological Diversity (CBD Secretariat 2015a,b,c).

3.2 Protected Areas

The Chilean government has the legal capacity to protect natural marine resources by designating Marine Protected Areas (MPAs), including Nature Sanctuaries, Wetlands, Marine Parks, Marine Reserves, and Multiple-Use Marine Protected Areas (Vásquez-Lavín and Simon 2013). In 2003, the Chilean government instituted several initiatives regarding the protection of marine coastal environments, including the launch of a National Biodiversity Strategy, with the objectives of "protecting marine and coastal resources, improving the public-private partnerships, and promoting sustainable and local-supportive economic activities (e.g., ecotourism)" (IUCN-WCPA 2008).

In 2008, the Chilean government designated all waters within its EEZ as the Chilean National Cetacean Protection Zone, where intentional catch, harassment, transportation, and commercialization of cetacean species is prohibited (Hoyt 2011). The sanctuary includes a framework for the development of whale-watching regulations, contingency plans for ship strikes, and the creation of a cetacean sighting database and MPAs (Hoyt 2011). The U.S. and Chile are working together to improve the management of their MPAs under the U.S.-Chile Environmental Cooperation Agreement (U.S. Department of State 2015).

Although there are several MPAs in the EEZs of Chile and Peru, there are no MPAs in the proposed survey areas (Wood 2007; Hoyt 2011; Ministry of Environment 2014; Gelcich et al. 2015; IUCN and UNEP-WCMC 2015; MPAtlas 2015a). The closest MPA to the northern proposed survey area is in Peruvian waters; Punta Coles National Reserve is a no-take area located ~100 km to the north (IUCN and UNEP-WCMC 2015; MPAtlas 2015b). The next closest MPA is La Rinconada Marine Reserve ~130 km to the south; it is an important habitat for northern (Peruvian) scallops (Undersecretary of Fishing 1997; Wood 2007; Government of Chile 2015).

The closest MPA to the central proposed survey area is Bosque de Calabacillo de Navidad Nature Sanctuary; it is located ~50 km east of the proposed central and southern survey areas. It is dedicated to the conservation of the biodiversity of a kelp forest and its biological resources (Ministry of Environment 2013). The next closest MPA is Las Cruces Marine and Coastal Protected Area, located ~60 km to the east (The Nature Conservancy 2015). It is a no-take area consisting of 10 ha in the intertidal and subtidal zones. Islas Choros-Damas and Isla Chañaral marine reserves are located ~120 and 145 km to the north of the central proposed survey area, respectively (IUCN and UNEP-WCMC 2015). These MPAs include the waters within ~2 km around three islands (Choros, Damas, and Chañaral) forming the Humboldt Penguin National Reserve, created to protect the terrestrial nesting sites of Humboldt penguins and other bird species (Hoyt 2011). This region is also an important migration and feeding area for cetaceans, sea otters, and South American sea lions, because of coastal upwelling and complex sea floor environments (Hoyt 2011). Another two MPAs are located between the northern and central proposed survey areas: (1) Isla Grande de Atacama Multiple Use Marine & Coastal Protected Area has upwelling sites that may be important feeding areas for cetacean species (Hoyt 2011); and (2) Caldera MPA (just north of Isla Grande de Atacama) is a transitional area for various cetaceans, including bottlenose dolphins (Hoyt 2011).

In addition to Bosque de Calabacillo de Navidad Nature Sanctuary, there are a number of other MPAs located near the southern proposed survey area (Fig. 1). Rocas de Constitución Nature Sanctuary, ~20 km to the east of the proposed survey area, encompasses ~108 ha and is an important cultural and ecological location, serving as a nesting place for gulls, pelicans, and cormorants (Ministry of Environment n.d.). Islotes Lobería y Lobería Iglesia de Piedra de Cobquecura Nature Sanctuary, ~30 km northeast of the nearest proposed survey line and 250 ha in area, protects a known transit area for South American sea lions (Republic of Chile 1992). Península de Hualpén Nature Sanctuary is a no-take area ~40 km east of the proposed survey area (IUCN and UNEP-WCMC 2015). Lafken Mapu-Lahual Marine and Coastal Protected Area, ~15 km southeast of the nearest proposed survey line, includes upwelling systems; is important for the Lafkenche native peoples; contains high biodiversity including Peale's dolphin, other coastal cetaceans, sea otters, seabirds, penguins, and South American sea lions; and is a breeding site for native coastal and freshwater fish (Hoyt 2011).

Another three MPAs are located adjacent to the southern proposed survey area on the west coast of Chiloé Island. Pullinque Marine Reserve, ~35 km to the east and 7.4 km^2 in area, has the goal of preserving the stocks of the Chilean oyster (Advanced Conservation Strategies 2011). Islotes de Punihuil Natural Monument, ~30 km to the east, is a no-take area that includes three islands and their surrounding area, a breeding ground for Magellanic and Humboldt penguins, and a concentration area for blue whales (Lonely Planet 2015). Chiloé National Park, ~25 km to the east, is a land-based protected area with a proposed expansion into marine waters to protect blue, humpback, and killer whales, Chilean and Peale's dolphins, and other cetaceans (Hoyt 2011). Putemún Marine Reserve, on the east coast of Chiloé Island, was established to preserve stocks of the giant mussel *Choromytilus chorus* (Advanced Conservation Strategies 2011).

Two MPAs are located along mainland Chile, on the Gulf of Ancud, which separates mainland Chile from Chiloé Island. Bosque Fósil de Punta Pelluco Nature Sanctuary provides some protection to intertidal biodiversity (Advanced Conservation Strategies 2011). The Fiordo Comau-San Ignacio de Huinay Multiple Use Marine and Coastal Protected Area (MUMPA) encompasses 14 km of coastline and the adjacent marine area for the conservation of marine biodiversity, including bottlenose, Peale's and Chilean dolphins, and killer whales (Hoyt 2011).

Three MPAs are located along mainland Chile, on the Gulf of Corcovado. The Bahía TicToc-Golfo de Corcovado MUMPA, ~115 km east of the southern portion of the southern proposed survey area, has an area of ~979 km^2 and is described as one of the most important breeding and feeding areas for blue whales in the southern hemisphere; other important species in this highly biologically productive area include humpback and sei whales, Chilean dolphins, southern sardines, and seabirds such as penguins, shearwaters, and cormorants (Republic of Chile 2014a). Adjacent to this MUMPA is the Tic-Toc Marine Park in TicToc Bay, ~113 km east of the proposed survey area; this 90,000 ha MPA is a no-take area which protects one of the most biodiverse regions along the Chilean coast and is an important feeding and nursery ground for blue whales (Nature World News 2014). Other notable species include Peale's and Chilean dolphins, killer and humpback whales, Humboldt penguins, albatross species, and sea otters (Hoyt 2011). The Pitipalena-Añihué MUMPA, ~120 km east of the southern portion of the proposed survey area, protects an area of ~240 km^2 with the purposes of preserving the environmental quality, biodiversity and biological productivity of the local river and marine ecosystems, maintaining these resources for sustainable use, and enhancing opportunities for land-use development; this protection extends to water and waterbed quality, seabirds, cold water corals and sponges, red algae, *Actinia* sea anemones, prawns, marine mammals, and fish species of commercial importance (Republic of Chile 2014b).

3.3 Marine Mammals

Twenty-nine species of cetaceans (8 mysticetes and 21 odontocetes) and 3 pinniped species could potentially occur in the northern proposed survey area off Chile in the southeast Pacific Ocean. In addition to these, another 10 cetacean species (1 mysticete and 9 odontocetes) and one pinniped species could potentially occur in the central and southern proposed survey areas. The marine otter could also occur in coastal waters adjacent to the proposed survey areas. Six of the 44 marine mammal species are listed under the U.S. ESA as ***Endangered***: the southern right, humpback, fin, sei, blue, and sperm whales, and the marine otter.

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of marine mammals are given in § 3.6.1, § 3.7.1, and § 3.8.1 of the PEIS. The general distributions of marine mammals in the eastern tropical Pacific (ETP) are discussed in the PEIS in § 3.6.2.5 for mysticetes, § 3.7.2.5 for odontocetes, and § 3.8.2.5 for pinnipeds. The rest of this section deals with species distribution in the proposed survey areas off Chile in the southeast Pacific Ocean.

Information on the occurrence near the proposed survey areas, habitat, population size, and conservation status for each of the 44 marine mammal species is presented in Table 3. Although an additional 8 species of marine mammals are known to occur in the southeast Pacific Ocean, they are unlikely to occur within the proposed survey areas and are not discussed further here, because their distributions in this region are generally restricted to

TABLE 3. The habitat, occurrence, regional population sizes, and conservation status of marine mammals that could occur in or near the proposed survey areas in the southeast Pacific Ocean.

Species	Occurrence Northern Chile	Occurrence Central / Southern Chile	Habitat	Population Size	ESA[1]	IUCN[2]	CITES[3]
Mysticetes							
Southern right whale	Rare	Rare	Coastal, oceanic	12,000[4]	EN	CR	I
Pygmy right whale	–	Rare	Coastal, oceanic	N.A.	NL	DD	I
Humpback whale	Common	Common	Coastal, shelf, pelagic	42,000[4]	EN[5]	LC	I
Common minke whale	Rare	Uncommon	Coastal, pelagic	515,000[6]	NL	LC	I
Antarctic minke whale	Rare	Uncommon	Coastal, pelagic	515,000[6]	NL	DD	I
Bryde's whale	Common	Common	Coastal, pelagic	10,411[7]	NL	DD	I
Sei whale	Uncommon	Uncommon	Mostly pelagic	10,000[8]	EN	EN	I
Fin whale	Uncommon	Common	Shelf, slope, pelagic	15,000[8]	EN	EN	I
Blue whale	Common	Common	Coastal, shelf, pelagic	2300 true[4]; 1500 pygmy[8]	EN	EN	I
Odontocetes							
Sperm whale	Common	Common	Pelagic, deep seas	4,145[7]	EN	VU	I
Dwarf sperm whale	Rare	Rare	Deep shelf, pelagic	11,200[9]	NL	DD	II
Pygmy sperm whale	Rare	Rare	Deep shelf, pelagic	N.A.	NL	DD	II
Cuvier's beaked whale	Uncommon	Uncommon	Slope, pelagic	20,000[9]	NL	LC	II
Shepherd's beaked whale	–	Rare	Pelagic	N.A.	NL	DD	II
Southern bottlenose whale	–	Uncommon	Pelagic	72,000[10]	NL	LC	I
Hector's beaked whale	–	Rare	Pelagic	25,300[9]	NL	DD	II
Gray's beaked whale	Rare	Rare	Pelagic	25,300[9]	NL	DD	II
Pygmy beaked whale	Rare	Rare	Pelagic	25,300[9]	NL	DD	II
Andrew's beaked whale	–	Rare	Pelagic	25,300[9]	NL	DD	II
Strap-toothed whale	–	Rare	Pelagic	25,300[9]	NL	DD	II
Spade-toothed whale	–	Rare	Pelagic	25,300[9]	NL	DD	II
Blainville's beaked whale	Uncommon	Uncommon	Pelagic	25,300[9]	NL	DD	II
Chilean dolphin	–	Uncommon	Coastal	N.A.	NL	NT	II
Rough-toothed dolphin	Rare	–	Oceanic	107,633[11]	NL	LC	II
Common bottlenose dolphin	Abundant	Common	Coastal, shelf, pelagic	335,834[11]	NL	LC	II
Striped dolphin	Rare	Rare	Shelf edge, pelagic	964,362[11]	NL	LC	II
Short-beaked common dolphin	Abundant	Abundant	Coastal, shelf	1,766,551[12]	NL	LC	II
Long-beaked common dolphin	Uncommon	–	Coastal, shelf	N.A.	NL	DD	II
Dusky dolphin	Abundant	Abundant	Shelf, slope	N.A.	NL	DD	II
Peale's dolphin	–	Uncommon	Coastal	N.A.	NL	DD	II
Hourglass dolphin	–	Rare	Pelagic	144,300[13]	NL	LC	II
Southern right whale dolphin	Uncommon	Common	Mostly pelagic	N.A.	NL	DD	II
Risso's dolphin	Common	Uncommon	Mostly shelf, slope	110,457[11]	NL	LC	II
Pygmy killer whale	Rare	Uncommon	Deep, pantropical	38,900[9]	NL	DD	II
False killer whale	Uncommon	Rare	Pelagic	39,800[9]	NL	DD	II
Killer whale	Rare	Rare	Coastal, shelf, pelagic	8,500[14]	NL	DD	II
Long-finned pilot whale	Common	Common	Coastal, pelagic	200,000[8]	NL	DD	II
Short-finned pilot whale	Uncommon	Uncommon	Coastal, pelagic	589,315[7]	NL	DD	II
Burmeister's porpoise	Uncommon	Uncommon	Coastal	N.A.	NL	DD	II
Pinnipeds							
Juan Fernández fur seal	Rare	Rare	Coastal, pelagic	32,278[15]	NL	LC	II
South American fur seal	Common	– / Rare[16]	Coastal, shelf, slope	24,589[17]	NL	LC	II
South American sea lion	Abundant	Abundant	Coastal, shelf	255,036[18]	NL	LC	NL
Southern elephant seal	Extralimital	Rare	Coastal, pelagic	640,000[19]	NL	LC	II
Lutrinids							
Marine otter	Rare	Rare	Coastal	789-2131[20]	EN	EN	I

N.A. = Not available. '–' = Absent from proposed survey area(s).

[1] U.S. Endangered Species Act (NMFS 2015a; USFWS 2015): EN = Endangered; NL = Not Listed.
[2] Classification from the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (IUCN 2015): CR = Critically Endangered; EN = Endangered; VU = Vulnerable; NT = Near Threatened; LC = Least Concern; DD = Data Deficient.
[3] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2015): Appendix I = Threatened with extinction; Appendix II = not necessarily now threatened with extinction but may become so unless trade is closely controlled.
[4] IWC (2015).
[5] NMFS has recently (April 2015) proposed that 14 distinct population segments (DPSs) of humpback whales should be recognized and that 10 of those should be delisted, including the Southeastern Pacific DPS (NMFS 2015b).
[6] Best estimate for the Southern Hemisphere from 1992/1993 to 2003/2004 sighting data; common and Antarctic minke whales combined (IWC 2015).
[7] ETP (Gerrodette and Forcada 2002).
[8] Antarctic (Boyd 2002).
[9] ETP; for *Mesoplodon* spp., only one density was reported (Wade and Gerrodette 1993).
[10] South of 60°S from the 1885/1986–1990/1991 IWC/IDCR and SOWER surveys (Branch and Butterworth 2001).
[11] ETP, line-transect survey, August-December 2006 (Gerrodette et al. 2008).
[12] ETP, southern stock, 2000 survey (Gerrodette and Forcada 2002).
[13] South of the Antarctic Convergence in January (Kasamatsu and Joyce 1995).
[14] ETP (Forney and Wade 2006).
[15] 2005/2006 minimum population estimate (Osman 2008).
[16] Absent and rare in the proposed central and southern survey areas, respectively.
[17] Population in Chile (Venegas et al. 2002).
[18] Pacific population, Chile and Peru (Dans et al. 2012).
[19] Southern Ocean population (Hindell and Perrin 2009).
[20] Peruvian coast (Valqui 2012a).

(a) latitudes south of ~40°S: Arnoux's beaked whale (*Berardius arnuxii*), Commerson's dolphin (*Cephalorhynchus commersonii*), and spectacled porpoise (*Phocoena dioptrica*);

(b) latitudes north of ~15°S: ginkgo-toothed beaked whale (*Mesoplodon ginkgodens*), Indopacific beaked whale (*Indopacetus pacificus*), and Fraser's dolphin (*Lagenodelphis hosei*); or

(c) farther offshore and more northerly waters: melon-headed whale (*Peponocephala electra*) and spinner dolphin (*Stenella longirostris*).

The waters off northern Chile form part of the Humboldt Current LME, characterized by strong upwelling of nutrient-rich equatorial waters. The upwelling is mostly aseasonal in northern Chile and species composition in this region may be more dependent on interannual variability, such as that caused by El Niño events, rather than intra-annual (seasonal) variability (Aguayo-Lobo et al. 1998; Thiel et al. 2007). Thus, both tropical and temperate species could occur off northern Chile, depending on the environmental conditions at the time of the survey. In contrast, upwelling in the central/southern region of Chile is more seasonal in nature, and the area is characterized by cold Humboldt Current water (Aguayo-Lobo et al. 1998; Thiel et al. 2007). Thus, cold water high-latitude species are more likely to occur in this region.

Little is known about the distributions of most cetacean species in the proposed survey areas off Chile, but the available information is provided in the species descriptions below. Most information is taken from Aguayo-Lobo et al. (1998), who provided a detailed summary on the occurrence of cetaceans in all Chilean waters compiled from several sources and separated into northern, central, and southern Chile. The northern region extended as far south as 32.2°S, inclusive of the northern and most of the central proposed survey areas. The central region extended from 32.2 to 39.9°S, including the remainder of the central and the northern half of the southern proposed survey areas. The southern region extended from 40°S to the Antarctic Convergence at 60°S, including the southern half of the southern proposed survey area. The main data sources used were two reports prepared previously by those authors (Torres et al. 1990, Aguayo and Torres 1993 *in* Aguayo- Lobo et al. 1998) for submission to the General Secretariat of the Comisión Permanente del Pacífico Sur (CPPS). The authors revised and updated the information in those reports to provide a comprehensive assessment, adding information from French and American whaling records (Du Pasquier 1986 and Townsend 1935, respectively, *in* Aguayo-Lobo et al. 1998) as well as from scientific reports, technical papers, conference proceedings, unpublished data, and written personal communications that they had gathered over the previous 10 years and are held at the Chilean Antarctic Institute (INACH). They provided the number of occurrences and individuals of each species for northern, central, and southern Chile compiled from the sighting, stranding, and catch data.

Aguayo-Lobo et al. (1998) also reported relative abundance estimates (animals per day) for cetaceans available in the published and unpublished literature. For the northern region of Chile, most of these estimates came from a single sighting survey in the summer (December–January) of 1997–1998 conducted as part of the International Whaling Commission (IWC) Southern Ocean Whale and Ecosystem Research (SOWER) Program between 20.2°S and 32.2°S. Estimates were provided for December and January combined (Findlay et al. 1998 *in* Aguayo-Lobo et al. 1998) and for December alone (Hucke-Gaete 1998 *in* Aguayo-Lobo et al. 1998) from that survey.

Abundance estimates are also available from sighting surveys based out of Valparaíso, Chile (33.1°S), which encompassed an area extending as far west as Easter Island, as far south as the Juan Fernández Islands (33.8°S), and as far north as San Félix Island (26.3°S), which is ~900 km southwest of the northern proposed survey area (Aguayo et al. 1998). The surveys spanned the latitudinal boundaries of the central proposed survey area and overlapped with the southern portion of it near Valparaíso. The sighting surveys were conducted during fall and winter (May–September) 1993–1995 and used a relative abundance metric based on the number of animals sighted per day, with day defined as 7.9 h of survey effort with good sighting conditions. Capella et al. (1999) reported cetacean sightings during 1988–1995 around Chañaral Island (29°S) at the Humboldt Penguin National Reserve, ~800 km south of the northern proposed survey area and ~100 km north of the central proposed survey area; the vast majority of sighting effort in that study occurred from late spring through fall (November–April).

Cetacean occurrence information was also retrieved from two online data repositories: (1) the SIBIMAP-PSE (Sistema de Información para Biodiversidad Marina y áreas Protegidas del Pacífico Sudeste) database (available at http://cpps.dyndns.info/sibimap/cetaceos.html), which is a data repository developed by CPPS to facilitate dissemination of information among scientists and policy makers engaged in marine biodiversity conservation in southeast Pacific countries: Chile, Colombia, Ecuador, Panama, and Peru; and (2) the Ocean Biogeographic Information System (OBIS; http://iobis.org). The paucity of sightings from those databases in the proposed survey areas for most species is likely more a reflection of lack of effort rather than the actual distribution of those species in the area. In addition, sightings during a low-energy seismic survey conducted by SIO in May 2012 in the northern portion (~34–35°S, 72.4–74°W) of the proposed southern survey area have also been included in the species descriptions below (SIO 2012). PSOs onboard the seismic source vessel, the R/V *Melville*, watched for marine mammals for at least 149 h during 1105 km of seismic operations.

3.3.1 Mysticetes

3.3.1.1 Southern Right Whale (*Eubalaena australis*)

The southern right whale occurs throughout the Southern Hemisphere between ~20°S and 60°S (Kenney 2009). It migrates between summer foraging areas at high latitudes and winter breeding and calving areas at low latitudes (Kenney 2009). Its calving and breeding areas generally are located in nearshore waters, whereas the feeding grounds in the Southern Ocean apparently are located mostly in offshore pelagic waters (Kenney 2009). The largest breeding areas are found in Argentina, South Africa, and Australia (Kenney 2009), but there are also calving areas in Brazil, Auckland/Campbell Islands, Chile, and Peru (IWC 2001). The southern right whale is found primarily in water <100 m deep, but a few records have been reported farther offshore (Félix and Escobar 2011).

Southern right whales were exploited off the southern and central coasts of Chile during the whaling era; thus, the current population in that region is much reduced (Aguayo and Torres 1986; Aguayo-Lobo et al. 2008). The Chile-Peru subpopulation of the southern right whale (as recognized by the IUCN) occurs from southern Peru (Santillán et al. 2004; Van Waerebeek et al. 2009) to central Chile (Aguayo and Torres 1986; Aguayo-Lobo et al. 2008) during austral winter and spring, and off southern-most Chile during fall and summer (NMSF 2007; Félix and Escobar 2011). This population does not appear to be increasing (IWC 2007a; Aguayo-Lobo et al. 2008) and is estimated to number as few as 50 mature individuals (Galletti Vernazzani et al. 2011).

Aguayo-Lobo et al. (2008) reviewed all available records of southern right whales along the entire coast of Chile for the 1976–2008 post-whaling era; they reported 115 sightings of 218 individuals, including 37 calves. Concentrations of sightings occurred between 31°S and 41°S (48%) and between 18°S and 25°S (24%). The former overlaps with the southern portion of the central and most of the southern proposed survey areas; the latter encompasses the northern proposed survey area. Galletti Vernazzani et al. (2011) only considered 79 confirmed sightings of 134 whales (including 27 calves) between 1975 and 2010 for their analysis. They found aggregations in northern Chile between 22°S and 26°S, and in central and southern Chile between 30°S and 37°S; sightings north of 20°S were scarce.

Based on data compiled by Aguayo-Lobo et al. (2008), southern right whales were seen within the proposed survey areas from June through March; most sightings in Chile were made from August to October (Aguayo-Lobo et al. 2008; Galletti Vernazzani et al. 2011). From 1964 to 2008, most calves in Chilean waters were reported between 23°S and 25°S and between 32°S and 36°S (Aguayo-Lobo et al. 2008). Calves were reported from late June until early November; except for one calf sighted near 18.5°S in August, all other calves were seen south of 23.3°S (Aguayo-Lobo et al. 2008). Calves were seen off central Chile between the end of July and the end of October. Félix and Escobar (2011) reported that mother-calf pairs were recorded in Chile from June through December during 1964–2011, with a peak during September and October. Cow-calf pairs have been sighted as far north as 12.4°S in Peru (Santillán et al. 2004; Van Waerebeek et al. 2009).

CPPS (2014) used the data compiled in the SIBIMAP database to assess the distribution and habitat use of five large whales occurring in the southeast Pacific Ocean, including the southern right whale. There were 170 sightings of this species in the database during 1963–2010, with a continuous distribution along the coast of Chile to central Peru, mainly in winter and spring (June–November). They were unable to identify areas of concentration or migratory routes, but reported that most sightings occurred between June and October and between 20°S and 40°S. Mothers with calves were seen north of 40°S, primarily in September and October. There are no records of this species in the OBIS database for the proposed northern proposed survey area, but there are 22 and 59 historical whaling records for the central and southern proposed survey areas, respectively (Townsend 1935 *in* OBIS 2015).

3.3.1.2 Pygmy right whale (*Caperea marginata*)

The distribution of the pygmy right whale is thought to be circumpolar in the Southern Hemisphere between 30°S and 55°S where water temperatures are between ~5°C and 20°C (Kemper 2009). The pygmy right whale has been seen in oceanic as well as coastal environments, and it may move farther inshore in spring and summer based on food availability (Kemper 2009). Little is known regarding this species, because it is rarely seen at sea (Kemper 2009). The central and southern proposed survey areas are within its theoretical range, but it does not occur in northern Chile. One stranding record has been reported for Chile, on Chiloé Island, at 41.8°S (Cabrera et al. 2005). There are no records of this species in the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.1.3 Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is found throughout all oceans of the world (Clapham 2009), with recent genetic evidence suggesting three separate subspecies: North Pacific, North Atlantic, and Southern Hemisphere (Jackson et al. 2014). The humpback whale is highly migratory, traveling between mid- to high-latitude waters where it feeds during spring to fall and low-latitude breeding grounds in winter (Clapham 2009). Breeding grounds are in coastal areas, primarily in waters <200 m deep (e.g., Guidino et al. 2014), but migration routes can traverse deep pelagic areas (Félix and Guzmán 2014).

In the Southern Hemisphere, humpback whales migrate annually from summer foraging areas in the Antarctic to breeding grounds in tropical seas (Clapham 2009). The IWC recognizes seven breeding populations in the Southern Hemisphere that are linked to six foraging areas in the Antarctic (Clapham 2009). Humpback whales in the southeast Pacific belong to breeding stock 'G', with winter breeding grounds from June–September primarily off Columbia and Ecuador, to as far north as Panama and as far south as northern Peru; summer feeding grounds are found in the Antarctic and off Patagonian, Chile, as far north as 41°S (Felix and Haase 2001; Acevedo et al. 2013; Hucke-Gaete et al. 2013; Guidino et al. 2014). Bettridge et al. (2015) identified humpback whales at these breeding locations as the Southeastern Pacific DPS. Félix et al. (2011) estimated the southeast Pacific stock to number 6504 individuals.

The northern and central proposed survey areas lie between the winter breeding grounds and summer feeding grounds of the humpback whale. The southern end of the southern proposed survey area overlaps with a feeding ground located at ~41.5–44°S (Hucke-Gaete et al. 2013). Humpback whales are generally expected to be migrating northward during austral fall, but they have been seen in this area in feeding groups and mother–calf pairs primarily during austral summer/fall. Most sightings are in Corcovado Gulf, but some sightings were made offshore of Chiloé Island. Wood et al. (2015) also detected humpback whale calls in the Chiloé-Corcovado region during January 2012 to April 2013.

The migratory corridors of humpback whales are not well described in this region, but one study that combined satellite-tracking with SIBIMAP data showed that migration routes from Ecuador to the Antarctic could be both coastal and oceanic (up to 800 km offshore), with mothers with calves preferring more coastal routes (Félix and Guzmán 2014). Although the satellite tracking data were collected during the southward migration, sighting data suggested that the migration corridor is likely to be the same for both the southward and northward migrations (Félix and Guzmán 2014). Félix and Guzmán (2014) showed a cluster of sightings near the coast between ~29°S and 38°S during the northward migration (February–August); most offshore sightings were made near the Juan Fernández Islands.

CPPS (2014) reviewed 3599 records of this species in the SIBIMAP database during 1963–2010 and confirmed a primarily coastal migratory route along the South American coast with some individuals seen farther offshore, suggesting either a wide migration corridor or that some animals choose a more oceanic route. There are no records of this species in the OBIS database for the northern proposed survey area, but there are 5 and 37 historical whaling records within the central and southern proposed survey areas, respectively (Townsend 1935 *in* OBIS 2015).

3.3.1.4 Common Minke Whale (*Balaenoptera acutorostrata*)

The common minke whale has a cosmopolitan distribution ranging from the tropics and subtropics to the ice edge in both hemispheres (Jefferson et al. 2008). A smaller form (unnamed subspecies) of the common minke whale, known as the dwarf minke whale, occurs in the Southern Hemisphere, where its distribution overlaps with that of the Antarctic minke whale (*B. bonaerensis*) during summer (Perrin and Brownell 2009). The dwarf minke whale is generally found in shallower coastal waters and over the shelf in regions where it overlaps with the Antarctic minke whale (Perrin and Brownell 2009). The range of the dwarf minke whale is thought to extend as far south as 65°S (Jefferson et al. 2008) and as far north as 11°S in the western Pacific, 2°S off the Atlantic coast of South America, and Chile in the southeast Pacific (Perrin and Brownell 2009).

Although the theoretical range of the dwarf minke whale extends into the northern proposed survey area (Jefferson et al. 2008), there is a lack of sightings there. Capella et al. (1999) reported 2 sightings of 3 common minke whales near Chañaral Island in the Humboldt Penguin National Reserve, ~100 km north of the central proposed survey area; both sightings occurred during summer (January 1995). There are 4 records of common minke whale in the OBIS database for Chile, including 2 just to the north (29.0°S) of the central proposed survey area and 2 within the southern proposed survey area (Reyes 2006 *in* OBIS 2015). There were no records for the proposed survey areas in the SIBIMAP database (CPPS 2015).

3.3.1.5 Antarctic Minke Whale (*Balaenoptera bonaerensis*)

The Antarctic minke whale has a circumpolar distribution in coastal and offshore areas of the Southern Hemisphere from ~7°S to the ice edge (Jefferson et al. 2008). It is found between 60°S and the ice edge during the austral summer; in the austral winter, it is mainly found at mid-latitude breeding grounds. The South Pacific breeding ground is found in oceanic waters at 10–30°S, 170°E–100°W (Perrin and Brownell 2009).

Aguayo-Lobo et al. (1998) reported the northernmost occurrence of Antarctic minke whales at 23°S. Although the range of the Antarctic minke whale is thought to extend into the northern proposed survey area (Jefferson et al. 2008), there is a lack of sightings there. However, Aguayo et al. (1998) reported a relative abundance of 0.4/day for June–July 1995 between 26.3°S and 33.1°S. There are no records for the proposed survey areas in the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.1.6 Bryde's Whale (*Balaenoptera edeni/brydei*)

Bryde's whale occurs in all tropical and warm temperate waters in the Pacific, Atlantic, and Indian oceans, between 40°N and 40°S (Kato and Perrin 2009). In the southeast Pacific it occurs from the Equator to ~37°S. It is one of the least known large baleen whales, and its taxonomy is still under debate (Kato and Perrin 2009). *B. brydei* is commonly used to refer to the larger form or "true" Bryde's whale and *B. edeni* to the smaller form; however, some authors apply the name *B. edeni* to both forms (Kato and Perrin 2009; Rudolph and Smeenk 2009). The smaller form is restricted to coastal waters (Rudolph and Smeenk 2009). A recent genetic analysis suggests that Bryde's whales found off both coasts of South America belong to *B. brydei*, according to the classification of Wada et al. (2003), and showed genetic distinctiveness between South Pacific and South Atlantic Bryde's whales but no genetic difference between whales off Chile and Peru (Pastene et al. 2015). Although there is a pattern of movement toward the Equator in the winter and the poles during the summer, Bryde's whale does not undergo long seasonal migrations but rather remains in warm (>16°C) water year-round (Kato and Perrin 2009). Genetic evidence from the eastern South Pacific is consistent with a north to south movement of whales from the same population in the spring and summer (Pastene et al. 2015). Bryde's whale is frequently observed in biologically productive areas such as continental shelf breaks (e.g., Davis et al. 2002) and regions subjected to coastal upwelling (e.g., Gallardo et al. 1983; Siciliano et al. 2004).

CPPS (2014) examined 399 Bryde's whale records in the SIBIMAP database for 1963–2010 and confirmed that it does not undertake major north/south migrations, but that it may undertake important movements related to varying environmental conditions such as El Niño. Environmental modeling confirmed suitable habitat in the Southern Hemisphere year-round, mainly off Peru and out to the Galápagos Islands but extending into Chilean waters. During summer (December–May), there was a large area of suitable habitat as well as many sightings off south-central Chile, suggesting that the species may be distributed farther south during austral summer.

Aguayo-Lobo et al. (1998) reported that Bryde's whales occur in Chilean waters between 20°S and 36°S, with greater abundance in the north. They compiled 70 records (91 animals) for the northern region of Chile and 21 records (33 animals) for the central region, many of which were within the northern and central/southern proposed survey areas, respectively. Reported relative abundance estimates were 2.3–2.6/day between 20.2°S and 32.2°S and 0.5/day between 32.2°S and 40°S from the SOWER sighting survey in December 1997–January 1998. There are 35 records of this species in the SIBIMAP database for Chile (CPPS 2015), many of which are in the northern proposed survey area. That database also includes one record of this species south of Chiloé Island at ~43.8°S. Although there are records of Bryde's whale in the OBIS database in the southeast Pacific, there are no records for Chile (OBIS 2015).

3.3.1.7 Sei Whale (*Balaenoptera borealis*)

The sei whale occurs in all ocean basins and is primarily an oceanic species (Horwood 2009). It undertakes seasonal migrations to feed in subpolar latitudes during summer and returns to lower latitudes during winter to calve (Horwood 2009). In the Southern Hemisphere, the sei whale typically concentrates between the Subtropical and Antarctic convergences during summer (Horwood 2009). It has been observed feeding in association with blue whales northwest of Chiloé Island in February and March (Galletti Vernazzani et al. 2005). Exact locations of its breeding and calving grounds are not known. The sei whales likely would be migrating northward to calving grounds during austral fall.

Aguayo-Lobo et al. (1998) compiled 4 records (4 animals) of sei whales in the northern region of Chile, 15 records (18 animals) in the central region, and 2 records (3 animals) in the southern region since the end of commercial whaling in 1982. Relative abundance estimates were 0.1–0.2/day between 20.2°S and 32.2°S and 1.1/day between 32.2°S and 40°S from the December 1997–January 1998 SOWER survey. Aguayo et al. (1998) reported a relative abundance of 0.1/day between 26.3°S and 33.1°S for May 1994. Wood et al. (2015) detected a possible sei whale during acoustic recordings in the Chiloé-Corcovado region during January 2012 to April 2013. There is one sei whale record in the OBIS database within the southern proposed survey area (Reyes 2006 *in* OBIS 2015), but there are no records for the other two proposed survey areas. There are 34 records of sei whales in the SIBIMAP database (CPPS 2015), all between 30.4°S and 44°S.

A recent (April–June 2015) mass stranding or strandings of sei whales was reported for the area between the Gulf of Penas and Puerto Natales (~47–52°S) in southern Chile (CBC News 2015), south of the southern proposed survey area. Thirty-seven sei whales were found dead on the beach in April, and 337 whales believed to be sei whales, including 32 skeletons, were seen during an observation flight in June. Although the cause of death has not been determined, human intervention was ruled out.

3.3.1.8 Fin Whale (*Balaenoptera physalus*)

The fin whale is widely distributed in all the world's oceans (Gambell 1985), although it is most abundant in temperate and cold waters (Aguilar 2009). Nonetheless, its overall range and distribution are not well known (Jefferson et al. 2008). The fin whale most commonly occurs offshore, but can also be found in coastal areas (Aguilar 2009). Most populations migrate seasonally between temperate waters where mating and calving occur in winter, and polar waters where feeding occurs in summer (Aguilar

2009). However, recent evidence suggests that some animals may remain at high latitudes in winter or low latitudes in summer (Edwards et al. 2015). The fin whale is known to use the shelf edge as a migration route (Evans 1987). Sergeant (1977) suggested that fin whales tend to follow steep slope contours, either because they detect them readily, or because the contours are areas of high biological productivity. However, fin whale movements have been reported to be complex, and not all populations follow this simple pattern (Jefferson et al. 2008).

In the Southern Hemisphere, fin whales are typically distributed south of 50ºS in austral summer, and they migrate northward to breed in winter (Gambell 1985). The distribution of fin whales in the proposed survey areas is not well known. A recent analysis of fin whale abundance globally suggests that there may be a hiatus in fin whale distribution in tropical waters, with the northern proposed survey area falling at the northernmost end of their distribution (Edwards et al. 2015). Recent studies have shown fin whales feeding near the coast in northern Chile at 23°S during July–October in waters 30–1000 m deep (Pacheco et al. 2015) and near Chañaral Island (29°S) at the Humboldt Penguin National Reserve (Perez et al. 2006).

Aguayo-Lobo et al. (1998) compiled 3 records of 7, 15 records of 31, and 2 records of 3 fin whales for the northern, central, and southern regions of Chile, respectively, since the end of commercial whaling in 1982. Relative abundances were 0.1/day between 20.2°S and 32.2°S and 1.1/day between 32.2°S and 40°S from the December 1997–January 1998 SOWER survey. Aguayo et al. (1998) reported a relative abundance estimate of 0.8/day between 26.3°S and 33.1°S for June–July. Capella et al. (1999) reported 9 sightings (28 animals) of fin whales near Chañaral Island (~29.0°S, 71.6°W) in the Humboldt Penguin National Reserve; those occurred during summer (January 1995 and February 1993) and fall (April 1994). These sightings are also in the OBIS database (Reyes 2006 *in* OBIS 2015); there are 3 additional sightings in the OBIS database for the southern proposed survey area. In the SIBIMAP database, there are 8 records of fin whales for Chile (CPPS 2015), 7 of which are within the southern proposed survey area, and the other is ~130 km offshore from the central proposed survey area. SIO (2012) reported 13 sightings of 35 fin whales in the northern portion of the southern proposed survey area.

3.3.1.9 Blue Whale (*Balaenoptera musculus*)

The blue whale has a cosmopolitan distribution, but tends to be mostly pelagic, only occurring nearshore to feed and possibly breed (Jefferson et al. 2008). There are two subspecies in the Southern Hemisphere: *B.m. intermedia* (the true blue whale) in the Antarctic and *B.m. brevicauda* (the pygmy blue whale) in the sub-Antarctic zone (Sears and Perrin 2009). The Antarctic blue whale is typically found south of 55°S during summer, although some are known not to migrate (Branch et al. 2007). Blue whale migration is less well defined than some of the other rorquals, and their movements tend to be more closely linked to areas of high primary productivity, and hence prey, to meet their high energetic demands (Branch et al. 2007; CPPS 2014). Branch et al. (2007) reported that blue whale sighting rates were high in the southeast Pacific relative to the Antarctic; Chile was among the locations with the highest sighting rates.

A large feeding aggregation area for this species occurs in waters between 39°S and 44°S during February–April (Hucke-Gaete et al. 2004; Galletti Vernazzani et al. 2012). Passive acoustic monitoring shows blue whales to be present in the Chiloé-Corcovado region (~43°S–44°S, 71°W–73°W) from December to August with a peak during March–May and supports movement toward the ETP during June and July (Buchan et al. 2015; Wood et al. 2015). Genetic evidence suggests that blue whales from southern and central Chile and the ETP are from the same breeding population, which is distinct from that of the Antarctic (Torres-Florez et al. 2014). Antarctic blue whale calls were also detected in the Chiloé-Corcovado region during the austral summer as they passed through the area (Wood et al. 2015).

Aguayo-Lobo et al. (1998) considered the two subspecies of blue whale (*B. m. intermedia* and *B.m. brevicauda*) separately. They compiled 2 records of 2, 2 records of 3, and 1 record of 1 *B.m. intermedia* for the northern, central, and southern regions of Chile, respectively, since the end of commercial whaling in the region in 1982. Relative abundances were 0.1–0.2/day between 20.2°S and 32.2°S and 0.1/day between 32.2°S and 40°S from the SOWER survey in December 1997–January 1998. Aguayo et al. (1998) reported a relative abundance of 0.3/day between 26.3°S and 33.1°S for June–July. Aguayo-Lobo et al. (1998) reported 26 sightings of 34, 11 sightings of 11, and 1 sighting of 1 *B.m. brevicauda* for the northern, central, and southern regions of Chile, respectively; relative abundance estimates were 1.1–1.2/day between 20.2°S and 32.2°S, 0.6/day between 32.2°S and 40°S, and 0.3/day between 40°S and 53°S from the December 1997–January 1998 SOWER survey. Williams et al. (2011) used spatial modeling to calculate an abundance estimate of 303 blue whales for the SOWER survey area. The average reported relative abundance from 8 years of aerial surveys during February to April between 39°S–44°S and out to 37 km was 31.7 groups/1000 km, with a maximum of 169.4 groups/1000 km northwest of Chiloé Island (Galletti Vernazzani et al. 2012).

There are 234 sightings of blue whales in the SIBIMAP database for Chile, occurring along the length of the Chilean coast (CPPS 2015); 2 of these are near the northern proposed survey area and several are within the central and southern proposed survey areas. CPPS (2014) considered 596 blue whale sightings in the SIBIMAP database from 1963–2010 and found evidence of movement from the south of Chile off Chiloé Island, where they feed during austral fall, northward along the Humboldt Current upwelling to Chile and Peru. Although there are records of this species in the OBIS database for the southeast Pacific, there are no records for Chile (OBIS 2015).

3.3.2 Odontocetes

3.3.2.1 Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest of the toothed whales, with an extensive worldwide distribution from the edge of the polar pack ice to the Equator in both hemispheres where depths are >1000 m (Whitehead 2009). Sperm whale distribution is linked to their social structure: mixed groups of adult females and juveniles of both sexes generally occur in tropical and subtropical waters at latitudes less than ~40° (Whitehead 2009). After leaving their female relatives, males gradually move to higher latitudes with the largest males occurring at the highest latitudes and only returning to tropical and subtropical regions to breed.

Until 1982, sperm whales were hunted heavily all along the coast of Chile and out to ~110°W. Since that time, most sightings have been in the northern region of Chile, but sperm whales occur all the way south to the Drake Passage (Aguayo-Lobo et al. 1998). Sixty-three sightings of 266, 53 records of 163, and 13 records of 18 were compiled for the northern, central, and southern regions of Chile, respectively, since the end of the commercial hunt in 1982. Reported relative abundances were 2.3–11.1/day between 20.2°S and 32.2°S, 4.4/day between 32.2°S and 40°S, and 1.7/day between 40°S and 53°S from a sighting survey in December 1997–January 1998. Aguayo et al. (1998) reported relative abundances of 0.3/day and 1.9/day between 26.3°S and 33.1°S for May 1995 and June–July 1995, respectively.

Rendell et al. (2004) spent 8 months in 2000 (April–December) following sperm whales, both visually and acoustically, off Chile between 18.5°S and 25°S; encounter rates were higher south of

22.5°S, coinciding with upwelling in that region. There are numerous records of sperm whales from the proposed survey areas in the OBIS and SIBIMAP databases (CPPS 2015; OBIS 2015), primarily because they contain American whaling logbook records and sightings from focused sperm whale research, respectively, suggesting that sperm whales are common in the area both historically and currently. CPPS (2014) examined 6863 records in the SIBIMAP database during 1963–2010 and found that sperm whales were widely distributed throughout the southeast Pacific with major concentrations in areas of high primary productivity, including along the Humboldt Current. SIO (2012) reported a group of 2 in the northern portion of the southern proposed survey area.

3.3.2.2 Dwarf (*Kogia sima*) and Pygmy (*K. breviceps*) Sperm Whales

The dwarf and pygmy sperm whales are distributed widely throughout tropical and temperate seas, but their precise distributions are unknown because much of what we know of the species comes from strandings (McAlpine 2009). They are difficult to sight at sea, because of their dive behavior and perhaps because of their avoidance reactions to ships and behavior changes in relation to survey aircraft (Würsig et al. 1998). The two species are often difficult to distinguish from one another when sighted, but dwarf sperm whales may be more pelagic with a preference for deeper water (McAlpine 2009).

Both *Kogia* species are sighted primarily along the continental shelf edge and slope and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998; Jefferson et al. 2008). Several studies have suggested that pygmy sperm whales live mostly beyond the continental shelf edge, whereas dwarf sperm whales tend to occur closer to shore, often over the continental shelf (Rice 1998; Wang et al. 2002; MacLeod et al. 2004). Barros et al. (1998), on the other hand, suggested that dwarf sperm whales could be more pelagic and dive deeper than pygmy sperm whales. It has also been suggested that the pygmy sperm whale is more temperate and the dwarf sperm whale more tropical, based at least partially on live sightings at sea from a large database from the ETP (Wade and Gerrodette 1993). This idea is also supported by the distribution of strandings in South American waters (Muñoz-Hincapié et al. 1998).

Aguayo-Lobo et al. (1998) reported no records of dwarf sperm whales in the northern region of Chile, but one occurrence of an individual pygmy sperm whale, which was sighted near Iquique (20.2°S) in the northern proposed survey area. Aguayo-Lobo et al. (1998) also compiled 2 sightings of pygmy sperm whales and 3 sightings of dwarf sperm whales in the central region of Chile (32–40°S). One dwarf sperm whale sighting occurred near Valparaíso at 33.1°S in the central proposed survey area. They found no records of either species in southern Chile. There are no records of either species for the proposed survey areas in the OBIS or SIBIMAP databases (CPPS 2015). In the OBIS database, there are 2 records of pygmy sperm whales for the southern proposed survey area; there no records of dwarf sperm whales for any of the proposed survey areas (OBIS 2015).

3.3.2.3 Cuvier's Beaked Whale (*Ziphius cavirostris*)

Cuvier's beaked whale is the most widespread of the beaked whales, occurring in almost all temperate, subtropical, and tropical waters and even some sub-polar and polar ones (MacLeod et al. 2006). It is likely the most abundant of all beaked whales (Heyning and Mead 2009). Cuvier's beaked whale is found in deep water over and near the continental slope (Gannier and Epinat 2008; Jefferson et al. 2008).

Aguayo-Lobo et al. (1998) reported 4 sightings of 6, 6 sightings of 31, and 3 sightings of 3 for the northern, central, and southern regions of Chile, respectively; some of those sightings occurred in the central proposed survey area. Reported relative abundances were 2.0/day between 32°S and 47°S for March–April 1966 and 0-0.2/day between 20.2°S and 53°S for December 1997–January 1998 (Aguayo-

Lobo et al. (1998), and 0.1/day between 26.3°S and 33.1°S for May 1994 (Aguayo et al. 1998). The SIBIMAP database has one sighting of a Cuvier's beaked whale near the central proposed survey area at 30.5°S, 73.7°W (CPPS 2015). There are no records of Cuvier's beaked whale in the OBIS (2015) database for the proposed survey areas.

3.3.2.4 Shepherd's Beaked Whale (*Tasmacetus shepherdi*)

Based on known records, it is likely that Shepherd's beaked whale has a circumpolar distribution in the cold temperate waters of the Southern Hemisphere (Mead 1989). It is primarily known from strandings, most of which have been recorded in New Zealand (Pitman et al. 2006; Mead 2009). However, two strandings have occurred on the Juan Fernández Islands (Pitman et al. 2006; Mead 2009), which are located ~520 km west of the southern end of the central proposed survey area. There are no records of Shepherd's beaked whale for Chile in the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.5.5 Southern Bottlenose Whale (*Hyperoodon planifrons*)

The southern bottlenose whale can be found throughout the Southern Hemisphere from 30°S to the ice edge (Gowans 2009). Although it is not expected to occur in the waters of northern Chile, sightings have been made off central and southern Chile (MacLeod et al. 2006). Little is known about this species, because it is not well studied and there are no known areas of concentration (Gowans 2009).

Aguayo-Lobo et al. (1998) compiled 6 records of 23 and 8 records of 11 for the central and southern regions of Chile, respectively, including some within the central and southern proposed survey areas. Relative abundance estimates were 1.4, 0.1, and 2.3/day for March–April, October, and December of 1966, respectively, between 32°S and 47°S, and 0.27/day for February of 1982 between 32°S and 38.5°S (Aguayo-Lobo et al. 1998). The SIBIMAP database contains two records for Chile (CPPS 2015), including one just west of the central proposed survey area at 31.3°S, 73.4°W, and one offshore of the southern proposed survey area at ~34.1°S, 74.9°W. There are no records of southern bottlenose whales for Chile in the OBIS database (OBIS 2015).

3.3.5.6 Hector's Beaked Whale (*Mesoplodon hectori*)

Hector's beaked whale is thought to have a circumpolar distribution in temperate waters of the Southern Hemisphere (Pitman 2009). Based on the number of stranding records for this species, it appears to be quite rare. There are no records in the South Pacific between New Zealand and South America, but it is not clear if this is a gap in distribution or related to a lack of sighting effort (MacLeod et al. 2006). On the Atlantic coast of South America, it occurs as far north as 32°S off Brazil, and in the southwest Pacific, it occurs as far north as 35.2°S (MacLeod et al. 2006).

3.3.2.7 Gray's Beaked Whale (*Mesoplodon grayi*)

Gray's beaked whale is thought to have a circumpolar distribution in temperate waters of the Southern Hemisphere (Pitman 2009). In the southeast Pacific it is thought to occur from the Antarctic to central Peru, with the cold waters of the Humboldt Current likely enabling it to occur so far north (MacLeod et al. 2006). Aguayo-Lobo et al. (1998) reported no occurrences of Gray's beaked whale for northern or central Chile, and 3 records in the southern region, all south of 50°S. Aguayo-Lobo et al. (1998) also reported 16 records of 41, 2 records of 8, and 2 records of 5 unidentified mesoplodont whales for the northern, central, and southern regions of Chile, respectively; some of those could have been Gray's beaked whales. There are no records of Gray's beaked whale for Chile in the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.2.8 Pygmy Beaked Whale (*Mesoplodon peruvianus*)

The pygmy beaked whale is thought to occur mostly in tropical waters in the eastern Pacific (Pitman 2009). In Chile, strandings have occurred as far south as 29.2°S (MacLeod et al. 2006). It is likely that this species is the beaked whale previously known as *Mesoplodon* sp. "A" in the ETP (Pitman and Lynn 2001 *in* MacLeod et al. 2006). Aguayo-Lobo et al. (1998) compiled 4 records for the northern region of Chile, consisting of 3 sightings and 1 skull, and none for the central or southern regions; all records were near the Humboldt Penguin National Reserve (29°S). Aguayo-Lobo et al. (1998) also reported 16 records of 41 unidentified mesoplodont whales in northern Chile within the northern proposed survey area; some of these could have been pygmy beaked whales. Because this is primarily a tropical species, any sighting within the central or southern proposed survey areas would be extralimital. There are no records of the pygmy beaked whale for any of the proposed survey areas in either the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.5.9 Andrew's Beaked Whale (*Mesoplodon bowdoini*)

Andrew's beaked whale likely has a circumpolar distribution in temperate waters of the Southern Hemisphere (Baker 2001; Pitman 2009). Its range in the southwest Pacific is probably between 54.5°S and 32°S (Baker 2001). There are no records of this species along the west coast of South America, but it is unknown if this is a true gap in distribution or a general lack of information for that area (MacLeod et al. 2006).

3.3.5.10 Strap-toothed Whale (*Mesoplodon layardii*)

The strap-toothed whale is thought to have a circumpolar distribution in temperate and sub-Antarctic waters of the Southern Hemisphere, mostly between 32°S and 63°S (MacLeod et al. 2006; Jefferson et al. 2008). Based on the seasonality of stranding records, the strap-toothed whale likely undertakes a limited migration northward from Antarctic and sub-Antarctic latitudes during austral winter (Pitman 2009). There is an absence of records of this species from the west coast of South America, but the central and southern proposed survey areas are within its theoretical range (Jefferson et al. 2008).

3.3.5.11 Spade-toothed Whale (*Mesoplodon traversii*)

The spade-toothed beaked whale is the name proposed for the species formerly known as Bahamonde's beaked whale (*M. bahamondi*); genetic evidence has shown that it belongs to the species first identified by Gray in 1874 (van Helden et al. 2002). The spade-toothed beaked whale is considered relatively rare and is known from only four records, three from New Zealand and one from the Juan Fernández Islands, Chile (Thompson et al. 2012). The Juan Fernández Islands are located ~520 km west of the southern end of the central proposed survey area.

3.3.2.12 Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whale is found in tropical and warm temperate waters of all oceans; it has the widest distribution throughout the world of all mesoplodont species and appears to be common (Pitman 2009). In the southeast Pacific, it is thought to occur as far south as ~45°S (MacLeod et al. 2006). Aguayo-Lobo et al. (1998) found no occurrences of Blainville's beaked whales in either the northern or central regions of Chile, and only one record in the southern region, northwest of Chiloé Island; there was also one record from Easter Island. Aguayo-Lobo et al. (1998) also reported 16 records of 41, 2 records of 8, and 2 records of 5 unidentified mesoplodont whales for the northern, central, and southern regions of Chile, respectively; it is likely that many of those were Blainville's beaked whales. Several of the sightings were in the northern proposed survey area and one was in the central proposed survey area. There are no records of Blainville's beaked whale for any of the proposed survey areas in the SIBIMAP database (CPPS 2015). There is one record of a Blainville's beaked whale in the OBIS database for the southern proposed survey area at 36.5°S, 74°W (Reyes 2006 *in* OBIS 2015).

3.3.5.13 Chilean Dolphin (*Cephalorhynchus eutropia*)

The Chilean dolphin is found along the Chilean coast from Valparaíso to Cape Horn (Dawson 2009). The northernmost sighting of this species has been reported for ~32°S (Goodall et al. 1988). Although its range is not well known, it is generally thought to be restricted to shallow coastal waters with strong currents (Heinrich 2006). A 4-y study along the east coast of Chiloé Island in southern Chile resulted in a population size estimate of 73 for south Chiloé and 59 for central Chiloé during 2001–2004 (Heinrich 2006).

Aguayo-Lobo et al. (1998) compiled 221 records of 1229 for the central region of Chile and 56 records of 319 for the southern region. They reported relative abundances of 6.7/day for the waters between Concepción (36.7°S) and Valdivia (39.8°S), within the southern proposed survey area, and 1.13/day between Chiloé (41°S) and Navarino (55°SS). The Chilean dolphin is not expected to occur as far north as the northern proposed survey area. There are no records of Chilean dolphin in the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.2.14 Rough-toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is distributed worldwide in tropical to warm temperate oceanic waters (Miyazaki and Perrin 1994; Jefferson 2009). In the southeast Pacific, its range may extend as far south as northern Chile (Jefferson et al. 2008), with the northern proposed survey area being at the southern end of its range and the central proposed survey area outside its known range.

Aguayo-Lobo et al. (1998) reported only a single occurrence of a rough-toothed dolphin in Chilean waters, at 24.5°S, but suggested that individuals of this species likely travel from Peruvian waters into this region in search of food, particularly during El Niño years. There are no records within any of the proposed survey areas in the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.2.15 Common Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin occurs in tropical, subtropical, and temperate waters throughout the world (Wells and Scott 2009). In the southeast Pacific, it is generally seen from northern Chile to ~40°S with records as far south as the Magellan Strait (Olavarría et al. 2010). In many parts of the world, coastal and offshore ecotypes have been distinguished based on morphological, ecological, and physiological features (Jefferson et al. 2008). Whereas both the coastal and offshore forms are present in Chilean waters, the offshore form is more abundant (Sanino and Van Waerebeek 2008).

Aguayo-Lobo et al. (1998) reported 56 sightings of 5942, 14 sightings of 565, and no sightings of common bottlenose dolphins for the northern, central, and southern regions of Chile, respectively. Relative abundances were 135.0–309.2/day between 20.2°S and 32.2°S and 2.7–21.3/day between 32.2°S and 40°S from a sighting survey in December 1997–January 1998. Aguayo et al. (1998) reported relative abundances of 1.1 and 1.9/day between 26.3°S and 33.1°S for May 1994 and June–July 1995, respectively.

Capella et al. (1999) reported 9 sightings of a total of ~193–253 common bottlenose dolphins in the waters near Chañaral Island in the Humboldt Penguin National Reserve. This was the only species sighted there during all four seasons, with sightings during January, March, April, July, November, and December; there was no sighting effort in May or June. One of the sightings, in November 1991, was of a large mixed-species group of 170–230 common bottlenose dolphins and 100–140 long-finned pilot whales. Similarly, Pérez-Alvarez et al. (2015) reported a small resident population at Isla Chañaral and Isla Choros-Damas marine protected areas. Diaz-Aguirre et al. (2009) also reported the year-round presence of common bottlenose dolphins in central Chile from Punta Angeles (33.0°S) to Punta Gallo (33.2°S). Olavarría et al. (2010) compiled 28 sightings between 41.8°S and 45.8°S; sightings were reported from all months of the year except June and September.

In a study of drift gillnet and longline bycatch in northern Peru, common bottlenose dolphins constituted 13% of the recorded cetacean bycatch (Mangel et al. 2008). There are 55 records from Chile in the SIBIMAP database (CPPS 2015), including 2 in the northern proposed survey area and several in and around the central and southern proposed survey areas. There are 9 records in the OBIS database for the central proposed survey area, all around Chañaral Island; there are no records for the northern or southern proposed survey areas (OBIS 2015).

3.3.2.16 Striped Dolphin (*Stenella coeruleoalba*)

The striped dolphin has a cosmopolitan distribution in tropical to warm temperate waters from ~50°N to 40°S (Perrin et al. 1994; Jefferson et al. 2008). It occurs primarily in pelagic waters, but has been observed approaching shore where there is deep water close to the coast (Jefferson et al. 2008).

Aguayo-Lobo et al. (1998) reported 1 sighting of 60 striped dolphins in the northern region of Chile in the waters off Iquique (20.2°S) during the 1997–1998 SOWER survey. There is only one record for Chile in the SIBIMAP database, near Robinson Crusoe Island in central Chile (CPPS 2015). There are no records in the OBIS database for the proposed survey areas (OBIS 2015).

3.3.2.17 Short-beaked (*Delphinus delphis*) and Long-beaked (*D. capensis*) Common Dolphin

The common dolphin can be found in tropical and warm temperate oceans around the world (Perrin 2009). In general, the long-beaked common dolphin seems to prefer shallower, warmer water and occurs closer to the coast (Perrin 2009). In the southeast Pacific, the long-beaked common dolphin is distributed from northern Peru to northern Chile, whereas the short-beaked common dolphin occurs continuously as far south as central Chile; thus, the two species overlap in distribution off northern Chile, but only the short-beaked common dolphin occurs off central Chile (Perrin 2009). In a study of drift gillnet and longline bycatch in northern Peru, the common dolphin was the most frequently observed cetacean, constituting 47% of the recorded bycatch (Mangel et al. 2008).

Aguayo-Lobo et al. (1998) compiled 9 sightings of 908, 10 sightings of 1732, and 1 sighting of 2 short-beaked common dolphins for the northern, central, and southern regions of Chile, respectively. Estimated relative abundances were 5.0–27.5/day between 20.2°S and 32.2°S and 0.1/day between 32.2°S and 40°S from a sighting survey in December 1997–January 1998 (Aguayo-Lobo et al. 1998). Estimated relative abundances between 26.3°S and 33.1°S were 0.8, 10.8, and 3.2/day for September 1993, 1994, and 1995, respectively, 193.0/day for May 1994, and 5.1/day for June–July 1995 (Aguayo et al. 1998). There is one record of short-beaked common dolphins in the SIBIMAP database at 30°S, 72.5°W, within the central proposed survey area at ~30°S, 72.5°W, one record within the southern proposed survey area at ~36.1°S, 74.1°W, and several farther offshore from those areas. There are no records in the OBIS database for the proposed survey areas (OBIS 2015).

For long-beaked common dolphins, Aguayo-Lobo et al. (1998) reported 2 sightings of 301 animals in northern Chile; one sighting was of 300 in the waters off Iquique (20.2°S) from the December 1997–January 1998 SOWER survey. There are no records of long-beaked common dolphins for the proposed survey areas in the OBIS or SIBIMAP databases (CPPS 2015; OBIS 2015).

3.3.2.18 Dusky Dolphin (*Lagenorhynchus obscurus*)

The dusky dolphin occurs throughout the Southern Hemisphere primarily over continental shelves and slopes, but it is sometimes found over deep water close to continents or islands (Van Waerebeek and Würsig 2009). Along the west coast of South America, it is present from northern Peru to Cape Horn. In the southeast Pacific, it is primarily limited to within ~90 km from shore (Van Waerebeek 1992). The dusky dolphin is commonly seen in Peruvian coastal waters in large feeding aggregations of many hundreds or thousands in association with the common dolphin (Van Waerebeek and Würsig 2009).

Dusky dolphins are common in northern Chile, where they have been hunted for human consumption and incidentally caught in the gillnet fisheries, and in southern Chile, where they were hunted for bait in the crab fishery (Aguayo-Lobo et al. 1998). Aguayo-Lobo et al. (1998) reported 37 sightings of 1076 animals, 39 sightings of 492, and 30 sightings of 1117 dusky dolphins in the northern, central, and southern regions of Chile, respectively, many of which were in the proposed survey areas. Reported relative abundances were 7.9–22.5/day between 20.2°S and 32.2°S and 0.1/day between 32.2°S and 40°S, from a sighting survey in December 1997–January 1998. Aguayo et al. (1998) reported a relative abundance of 0.3/day between 26.3°S and 33.1°S during June–July 1995.

Dusky dolphins were the most frequently sighted cetacean by Capella et al. (1999) in the waters near Chañaral Island in the Humboldt Penguin National Reserve, with 8 sightings of ~1310–1750; group size estimates were 50–450. Dusky dolphins were sighted there during summer (January 1995 and February 1990 and 1993) and fall (April 1991 and 1994) (Capella et al. 1999).

In a study of drift gillnet and longline bycatch in northern Peru, dusky dolphins constituted 29% of the recorded cetacean bycatch (Mangel et al. 2008). There are 6 records in the SIBIMAP database (CPPS 2015), including two in the northern proposed survey area, one adjacent to the central proposed survey area, and two in the southern proposed survey area. There are 8 records in the OBIS database near the central proposed survey area, all around Chañaral Island, and 7 records in the southern proposed survey area; there are no records for the northern proposed survey area (OBIS 2015).

3.3.5.19 Peale's Dolphin (*Lagenorhynchus australis*)

Peale's dolphin is a South American species that is common from ~59°S to ~39°S on the Pacific coast and to ~44°S on the Atlantic coast (Goodall 2009b). The northernmost record of this species in the eastern South Pacific is just north of Valparaíso, Chile, at 32.9°S (Goodall et al. 1997b); thus, Peale's dolphin is not expected to occur within the northern proposed survey area. Peale's dolphin is a coastal species, often found associated with kelp beds and in water <200 m deep (Heinrich 2006). A 4-y study along the east coast of Chiloé Island in southern Chile resulted in a mean local population size of 78 for south Chiloé and 123 for central Chiloé during 2001–2004 (Heinrich 2006).

Aguayo-Lobo et al. (1998) compiled 15 records of 36 Peale's dolphin for the central region of Chile, including some within the central proposed survey area, and 693 records of 2802 for southern Chile, including some within the southern proposed survey area. There are 28 records of this species in the OBIS database north of 44°S along the Chilean coast (Reyes 2006 *in* OBIS 2015); one of those, at 33.6°S, is within the central proposed survey area, five are within the southern proposed survey area, and the remainder are found farther inshore in the Corcovado Gulf and east of Chiloé Island. There are no records in the SIBIMAP database (CPPS 2015).

3.3.5.20 Hourglass Dolphin (*Lagenorhynchus cruciger*)

The hourglass dolphin occurs in all parts of the Southern Ocean, with most sightings between 45°S and 60°S (Goodall 2009a). Although it is pelagic, it is also sighted near banks and islands (Goodall

2009a). The northernmost sighting in the eastern South Pacific is of 8 individuals near Valparaíso, Chile, at 33.7°S (Goodall 1997); this is at the southern limit of the central proposed survey area. However, the lack of photographic evidence from that sighting (Aguayo et al. 1998), along with difficulty in distinguishing among *Lagenorhynchus* species at the time the sighting was made (Goodall et al. 1997a), and a lack of other sightings at this latitude suggest that this species is likely to be rare that far north. Aguayo-Lobo et al. (1998) reported 30 records of 99 hourglass dolphins for the southern region of Chile, all south of ~49°S. Thus, this species would not be encountered in the northern proposed survey area, and is expected to be rare at best in the central and southern proposed survey areas.

3.3.2.21 Southern Right Whale Dolphin (*Lissodelphis peronii*)

The southern right whale dolphin is distributed between the Subtropical and Antarctic convergences in the Southern Hemisphere (Jefferson et al. 1994). In the southeast Pacific, it is most often seen between 25°S and 55°S in offshore waters, but has been observed near the coast of Chile (Lipsky 2009). The northernmost record is 12°S off central Peru (Jefferson et al. 2008).

Southern right whale dolphins are generally less common off northern Chile than farther south (Aguayo-Lobo et al. 1998). Aguayo-Lobo et al. (1998) reported 14 sightings of 583, 21 sightings of 2095, and 35 sightings of 2533 for the northern, central, and southern regions of Chile, respectively. No relative abundance estimate was available for the northern region, but estimates of 0.4–5.0/day between 32.2°S and 40°S and 22.9–80/day between 40°S and 53°S were reported from a sighting survey in December 1997–January 1998; an estimate of 22.6/day was reported between 32°S and 47°S for March–April 1966 (Aguayo 1975 *in* Aguayo-Lobo et al. 1998).

There are 10 records of southern right whale dolphins for Chilean waters in the SIBIMAP database, including one within the central proposed survey area, and the remainder between 39.1°S and 45.2°S, including within the southern proposed survey area (CPPS 2015). In the OBIS database, there is one record for the southern proposed survey area at ~40°S, 74.2°; there are no records for the other proposed survey areas (OBIS 2015). SIO (2012) reported a group of 2 in the northern portion of the southern proposed survey area.

3.3.2.22 Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide (Kruse et al. 1999). Although it occurs from coastal to deep water, it shows a strong preference for mid-temperate waters of the continental shelf and slope (Jefferson et al. 2014). Olavarría et al. (2001) reported that the occurrence of Risso's dolphin is continuous along the Chilean coast from ~20.2°S to 40°S, but that the majority of the records occurred in northern waters during austral summer; they seem to prefer waters >1000 m deep. Risso's dolphin is gregarious, with typical group sizes of 10–100 and a maximum group size of ~4000 (Jefferson et al. 2008).

Aguayo-Lobo et al. (1998) reported 25 sightings of 367, 9 sightings of 69, and 4 sightings of 4 Risso's dolphins for the northern, central, and southern regions of Chile, respectively. It was most common in northern Chile, with a relative abundance of 17.6/day between 20.2°S and 32.2°S from a sighting survey in December 1997–January of 1998; the relative abundance estimate for the central region was 0.5/day between 32.2°S and 40°S (Aguayo-Lobo et al. 1998).

There are 9 records in the OBIS database within the northern proposed survey area, all during December 1997; 6 records within the central proposed survey area, all during the summer except for one in July; and 7 records within the southern proposed survey area, during July and December (Reyes 2006 *in* OBIS 2015). There is only one record in the SIBIMAP database, within the central proposed survey area at 32.5°S (CPPS 2015).

3.3.2.23 Pygmy Killer Whale (*Feresa attenuata*)

The pygmy killer whale has a worldwide distribution in tropical and subtropical waters (Donahue and Perryman 2009), generally not ranging south of 35°S (Jefferson et al. 2008). It is known to inhabit the warm waters of the Indian, Pacific, and Atlantic oceans (Jefferson et al. 2008). It can be found in nearshore areas where the water is deep and in offshore waters (Jefferson et al. 2008). The pygmy killer whale is sighted frequently in the ETP (Donahue and Perryman 2009).

Aguayo-Lobo et al. (1998) reported only a single sighting of pygmy killer whales in Chilean waters, at 26°S, 73.2°W. The SIBIMAP database shows 15 records for Chilean waters; all are near the central and southern proposed survey areas (CPPS 2015). There are no records in the OBIS database (OBIS 2015).

3.3.2.24 False Killer Whale (*Pseudorca crassidens*)

The false killer whale is found in all tropical and warmer temperate oceans, especially in deep offshore waters (Odell and McClune 1999). It is primarily pelagic but can also be seen in shallow water near oceanic islands (Baird 2009). The false killer whale is widely distributed, but generally uncommon throughout its range (Baird 2009). It is gregarious and forms strong social bonds, as is evident from its propensity to strand en masse (Baird 2009). Its distribution along the Chilean coast is thought to be continuous throughout the northern and central regions (Flores et al. 2003).

Aguayo-Lobo et al. (1998) reported 4 sightings of 108 false killer whales in northern Chile, 3 of which were in the northern proposed survey area; one sighting was in each of the central and southern proposed survey areas. No relative abundance estimates were provided. The only record for Chile in the SIBIMAP database is from Easter Island (CPPS 2015). There are no records in the OBIS database for the proposed survey areas (OBIS 2015).

3.3.2.25 Killer Whale (*Orcinus orca*)

The killer whale is widely distributed in all oceans of the world, but is most common in temperate coastal waters (Ford 2009). It is very common in temperate waters but also occurs in tropical waters (Heyning and Dahlheim 1988), and it inhabits coastal as well as offshore regions (Budylenko 1981). It is thought to be rare throughout the ETP, eastern temperate Pacific, and eastern South Pacific (Forney and Wade 2006). However, sightings have been reported along the entire coast of Chile (Félix and Escobar 2011).

Aguayo-Lobo et al. (1998) reported 8 sightings of 18, 8 sightings of 35, and 13 sightings of 43 killer whales for the northern, central, and southern regions of Chile, respectively, including sightings in all three of the proposed survey areas. They reported relative abundance estimates of 0.4/day between 20.2°S and 32.2°S from a sighting survey in December 1997–January 1998 and 1.0/day between 32°S and 38.5°S from a survey in February of 1982. A relative abundance of 0.1/day was reported by Aguayo et al. (1998) between 26.3°S and 33.1°S for May 1994. Capella et al. (1999) reported 2 sightings near Chañaral Island in the Humboldt Penguin National Reserve: pods of 3 in November 1989 and 5 in July 1991; this was one of only 2 species sighted there during their limited winter surveys.

There are 78 records of killer whales in the SIBIMAP database (CPPS 2015), widely distributed along the coast of Chile, including all three of the proposed survey areas. In Peru, killer whales were sighted along the length of the country as far south as the border with Chile during Instituto del Mar del

Peru (IMARPE) sighting surveys in 1995–2003, but sightings were rare (Garcia-Godos 2004). There is one record in the OBIS database in the southern proposed survey area at ~38.4°S, 73.4°W; there are no records for the northern or central proposed survey areas (OBIS 2015).

3.3.2.26 Short-finned (*Globicephala macrorhynchus*) and Long-finned (*G. melas*) Pilot Whales

The short-finned pilot whale is generally found in tropical and warm temperate waters, whereas the long-finned pilot whale is distributed antitropically in cold temperate waters, with little overlap between the two species (Olson 2009). However, the west coast of South America, off northern Chile and southern Peru, is one region where their ranges do overlap. Short-finned pilot whale distribution does not generally range south of 40°S (Jefferson et al. 2008).

Sanino and Yáñez (2001) reported that long-finned pilot whales were present along the entire coast of Chile, whereas short-finned pilot whales were restricted to the north and central regions. Pilot whales are very social and are usually seen in groups of 20–90 (Olson 2009). They can often be seen in mixed-species aggregations. Capella et al. (1999) reported sighting 100–140 long-finned pilot whales in association with 170–230 common bottlenose dolphins 8 km northwest of Chañaral Island in the Humboldt Penguin National Reserve in November 1991.

Aguayo-Lobo et al. (1998) reported 4 sightings of 4 short-finned pilot whales in the northern region of Chile, one of which was at the southern end of the proposed survey area, but no sightings were made for the central or southern regions of Chile; relative abundance estimates were not available. They also reported 24 sightings of 310, 23 sightings of 337, and 28 sightings of 389 long-finned pilot whales for the northern, central, and southern regions of Chile, respectively. Relative abundances were 3.9–4.4/day between 20.2°S and 32.2°S and 5.0/day between 32.2°S and 40°S from the SOWER sighting survey in December 1997–January 1998. From a winter sighting cruise (June–July 1995), Aguayo et al. (1998) reported a relative abundance for long-finned pilot whales of 1.5/day between 26.3°S and 33.1°S.

There are 10 records of long-finned pilot whales in the OBIS database for the central proposed survey area and 16 records for the southern proposed survey area; there are no records for the northern proposed survey area (OBIS 2015). There are no records of short-finned pilot whales in any of the proposed survey areas (OBIS 2015). Similarly, there are no records of either species in the SIBIMAP database for the proposed survey areas (CPPS 2015).

3.3.2.27 Burmeister's porpoise (*Phocoena spinipinnis*)

Burmeister's porpoise occurs from ~5°S in northern Peru to ~40°S in Chile (Reyes 2009). It is a coastal, shallow water species limited to ~1000 m from shore and water depths < 25 m. In a study of drift gillnet and longline bycatch in northern Peru, Burmeister's porpoise constituted 6% of the recorded cetacean bycatch (Mangel et al. 2008).

Burmeister's porpoise is common in northern Chile, where it has been hunted for human consumption and is incidentally caught in the gillnet fisheries (Aguayo-Lobo et al. 1998). Aguayo-Lobo et al. (1998) compiled 273 sightings of 353 in the northern region of Chile, many of which were in the northern proposed survey area, and 43 sightings of 71 for the central region of Chile, many of which were in the southern proposed survey area. The only relative abundance estimate reported was 5.0/day between 28°S and 37°S from a sighting survey in late spring/early summer (November–December) 1964 (Clarke et al. 1978 *in* Aguayo-Lobo et al. 1998).

The SIBIMAP database contains 4 records of this species for southern Chile, all inshore of Chiloé Island; there are no records for northern or central Chile (CPPS 2015). There are two records in the OBIS database for the southern proposed survey area, but none in the other two proposed survey areas (OBIS 2015).

3.3.3 Pinnipeds

3.3.3.1 Juan Fernández Fur Seal (*Arctocephalus philippii*)

The Juan Fernández fur seal is the only pinniped endemic to Chile (Osman et al. 2010). It was thought to be extirpated, but was rediscovered in 1965 (Reijnders et al. 1993). The Juan Fernández fur seal inhabits three islands in the Juan Fernández Archipelago (Robinson Crusoe, Santa Clara, and Alejandro Selkirk) and the two San Félix Islands (Osman 2008; Osman et al. 2010). The largest breeding colony in the Juan Fernández Archipelago is found at Lobería Vieja on Alejandro Selkirk Island (Osman 2008). An extensive census of the population during the December 2005–January 2006 breeding season provided a total population estimate of 32,278 (Osman 2008).

Juan Fernández fur seals travel long distances from their breeding colonies to foraging areas; foraging patterns are primarily influenced by prey distribution, which leads to extended foraging trips (Francis et al. 1998). Vagrants have been sighted along the Pacific coast of South America from southern Peru to southern Chile (Reijnders et al. 1993; Jefferson et al. 2008); one individual traveled as far north as Colombia (Avila et al. 2014). Five females outfitted with a time-depth recorder traveled >500 km from their haul-out sites during foraging trips; although no individuals traveled north of 30°S, some traveled southeast towards mainland Chile, as far as 41°S, 76°W (Francis et al. 1998). Seven lactating females tagged with satellite transmitters traveled a mean distance of 1394 km (maximum 2921 km) during foraging trips in January and February lasting 11–41 days away from their pups (Osman 2008). Most foraging trips appeared to be associated with the productive waters of the Humboldt Current system, with most fur seals traveling south and southeast and one traveling to the coast near Concepcion Bay (~37°S), within the southern proposed survey area.

3.3.3.2 South American Fur Seal (*Arctocephalus australis*)

The South American fur seal occurs along the west and east coasts of South America; on the west coast, it is found from Peru to west of Tierra del Fuego (Arnould 2009). It has a discontinuous distribution, being absent along the coast of Chile from ~23°S to 43°S (Cárdenas-Alayza 2012), thus would not occur in the central or most of the southern proposed survey areas. It is thought to forage along the continental shelf and slope, but it may be seen as far as 600 km offshore (Jefferson et al. 2008). Its at-sea behavior is strongly influenced by bathymetry, sea state, and current direction (Dassis et al. 2012). Breeding occurs from mid October through mid December on rocky coasts (Jefferson et al. 2008). The breeding season in southern Chile occurs about one month later than elsewhere in South America (Pavés and Schlatter 2008). Small numbers of South American fur seals are hunted for human consumption in Peru and Chile (Jefferson et al. 2008), and their numbers in Peru have been severely depleted by El Niño events (Stevens and Boness 2003).

Sielfeld (1999) identified one breeding colony and 11 haul-out sites for South American fur seals in Chile Region I, which corresponds to the latitudinal range of the northern proposed survey area; he estimated that 750 fur seals use this region. Although there is only one breeding site in northern Chile, there are an additional 9 haul-out sites in Chile Region II, which extends south to ~26°S; Region II is used by ~850 fur seals. No breeding colonies or haul-out sites were reported for Regions III to IX (~26–41°S), the presence of colonies and haul-out sites was uncertain for Regions X and XI (~41–50°S), and the majority of fur seals occurred at breeding and haul out sites in Region XII, south of 50°S (Sielfeld 1999; Venegas et al. 2002). During 2012, Oliva et al. (2015) reported eight breeding colonies between

43.0°S and 48.4°S, including four main rookeries at Isla Guafo, Isla Paz, Caleta Dyer, and Isla Breaksea. The largest breeding colony, Isla Guafo, is located within the southern portion of the southern survey area. Five additional non-breeding haul-out sites were found during summer 2012, and another three haul-out sites were reported during winter 2011 (Oliva et al. 2015). During summer 2012, 8901 fur seals were counted; lower numbers in the region during winter suggest a southward migration to the Magallanes at that time (Oliva et al. 2015). SIO (2012) reported 70 sightings of *Arctocephalus* sp. in the northern portion of the southern proposed survey area.

3.3.3.3 South American Sea Lion (*Otaria flavescens*)

The South American sea lion is widely distributed along the South American coastline from Peru in the Pacific to southern Brazil in the Atlantic (Cappozzo and Perrin 2009). It is thought to feed primarily at night and return to land (at both breeding and haul-out sites) during the day (Sepúlveda et al. 2001, 2015a). It feeds in waters of the continental shelf, with foraging trips lasting a few days out to an average distance of ~200 km (Cappozzo and Perrin 2009). Sepúlveda et al. (2015b) reported that sea lions foraging off northern Chile, where the shelf is narrow, make shallower dives than those off southern Chile where the shelf is wider; sea lions in the northern region were shown to be epipelagic foragers whereas those in the south were feeding on pelagic and benthic fish. Sea lions that were tagged along the west coast of Chiloé Island did not move westward into offshore waters to forage, but rather entered the Gulf of Ancud.

Seasonal variations in abundance at both breeding and haul-out sites are related to the timing of breeding, with higher numbers at breeding sites during December–March with a peak in February, and lower numbers at haul-out sites (Sepúlveda et al. 2001, 2015a). Inter-annual variation in abundance at breeding sights in northern Chile is highly affected by El Niño events, with females taking longer foraging trips and having high rates of mortality and lower birth rates (Sepúlveda et al. 2015a).

Based on a 2007 census, there were 96 colonies (40 breeding colonies and 56 haul outs) of South American sea lions in northern Chile from 18°S to 32°S, with an estimated population size of 70,286; this region represents 54% of the total Chilean population of ~130,000 (Dans et al. 2012). Several of the colonies are located adjacent to the northern proposed survey area; tracked sea lions have been reported within the study area (Sepúlveda et al. 2015b). Contreras et al. (2014) reported counts from aerial survey censuses for winter 2012 and summer 2013; there were 27,009 in the winter and 37,681 in the summer at 14 different sites from Punta Pichalo (19.6°S) to Punta Lobos, Iquique (21.0°S). For central Chile, there were 33 colonies (6 breeding colonies and 27 haul outs) in Regions V to IX from 32°S to 39.4°S, with an estimated population size of 18,179 in 2007 (Dans et al. 2012). In Regions X and XI, from 39.4°S to 43.8°S, adjacent to the southern proposed survey area, there were 60 breeding colonies and 33 haul outs with an estimated population size of 46,682. SIO (2012) reported 4 sightings of 12 in the northern portion of the southern proposed survey area.

3.3.3.4 Southern elephant seal (*Mirounga leonina*)

The southern elephant seal has an extensive range, with breeding sites on islands throughout the sub-Antarctic (Hindell and Perrin 2009). Animals from the breeding colony on Península Valdés, Argentina, likely migrate up both coasts of South America (Lewis et al. 2006). When not on land to breed or molt, southern elephant seals use most of the Southern Ocean (Hindell and Perrin 2009). Breeding occurs from September to November, and molting takes place from December to March (Sepúlveda et al. 2007). The post-molt pelagic foraging phase lasts ~7 months. Individuals have been seen hauled out to molt as far north as Antofagasta (23.5°S) in January (Pacheco et al. 2011) and during

November–January on Chañaral Island in the Humboldt Penguin National Reserve (Sepúlveda et al. 2007).

The proposed seismic survey is scheduled to occur while these animals would be foraging at sea post-molt. Although central Chile is considered part of the southern elephant seal's secondary range, northern Chile is not considered part of its range (Jefferson et al. 2008). However, extralimital records have been reported for northern Chile, Peru, and Ecuador (Lewis et al. 2006 *in* OBIS 2015). There are 6 records in the OBIS database for Chile north of 44°S, including 2 along the coast adjacent to the northern proposed survey area, 2 offshore from the central proposed survey area, 1 along the shore in between the northern and central proposed survey areas, and 1 along the shore in the southern proposed survey area; records for the northern and central proposed survey areas were from May through August, and the record from the southern proposed survey area was in February (Lewis et al. 2006 *in* OBIS 2015). Another 25 records exist farther south off Chile (Lewis et al. 2006 *in* OBIS 2015). SIO (2012) reported 1 elephant seal in the northern portion of the southern proposed survey area.

3.3.4 Lutrinids

3.3.4.1 Marine otter (*Lutra felina*)

The marine otter occurs along the west coast of South America from northern Peru to Cape Horn, but its distribution is fragmented based on the availability of suitable habitat (Valqui 2012b). The largest populations are thought to occur in Chilean waters (Jefferson et al. 2008), but no abundance estimates are available. Marine otters forage in the marine environment and use shelters in terrestrial habitats (Medina-Vogel et al. 2006). The feeding range of the marine otter extends inland by ~30 m and to ~150 m from shore (Castilla and Bahamondes 1979 and Ostfeld et al. 1989 *in* Medina-Vogel et al. 2006). Pups have been reported year-round in southern Chile, with a peak during September–November (Medina-Vogel et al. 2006).

The occurrence of the marine otter has been documented along the coast of Chile within the latitudinal range of all three proposed surveys (Valqui 2012b). Sielfeld and Castilla (1999) provided abundance estimates of 1.5/km of coastline for a 2-km section of the coastline in Chile Region I and 0.5–2.5/km for three different coastline surveys in Chile Region IV. Valqui (2012a) reported that numbers were 1.0–2.7/km, whereas Medina-Vogel et al. (2006) reported that numbers north of 29°S were 1.0–4.4/km. Medina-Vogel et al. (2006) reported 3.8/km in southern Chile, at ~39.7°S, from June 1999 to June 2000.

The marine otter would not be encountered during the proposed survey as it occurs only in coastal waters, although it could be encountered during transit to and from port.

3.4 Sea Turtles

Four species of sea turtle could occur in the proposed study areas in the southeast Pacific Ocean. The leatherback turtle and the South Pacific Distinct Population Segment (DPS) of the loggerhead turtle are listed as ***Endangered*** under the ESA. The green turtle, including the proposed East Pacific DPS (NMFS and USFWS 2015), and the olive ridley turtle are listed as ***Threatened*** under the ESA. On the IUCN Red List of Threatened Species (IUCN 2015), the East Pacific Ocean subpopulation of leatherback turtle is listed as *Critically Endangered,* the green and loggerhead turtles are listed as *Endangered*, and the olive ridley turtle is listed as *Vulnerable*. The hawksbill turtle (*Eretmochelys imbricata*) only occurs as far south as Peru in the southeast Pacific Ocean (Alfaro-Shigueto et al. 2010); thus, it is not discussed further.

There are no sea turtle nesting sites in Chile (Donoso et al. 2000). However, juvenile and sub-adult turtles use Chilean waters as migration routes and foraging areas (Sarmiento-Devia et al. 2015). Leatherback, green, and olive ridley turtles nest to the north of the proposed survey areas; loggerhead turtles do not nest in the eastern Pacific Ocean. Leatherback turtles are the most commonly reported sea turtle species in the offshore waters of Chile, whereas green turtles are most frequently encountered in nearshore waters.

General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of sea turtles is given in § 3.4.1 of the PEIS. The general distribution of sea turtles in the ETP is discussed in § 3.4.2 of the PEIS. The rest of this section focuses on their distribution in the proposed survey areas off Chile in the southeast Pacific Ocean.

3.4.1 Leatherback Turtle (*Dermochelys coriacea*)

The leatherback is the most widely distributed sea turtle, occurring from 71°N to 47°S (Eckert et al. 2012). During the non-breeding season, it ranges far from its tropical and subtropical nesting grounds, which are located from 38°N to 34°S (Eckert et al. 2012). In the eastern Pacific Ocean, leatherback nesting sites are found from Baja California, Mexico, to Colombia (Eckert 2002). Telemetry studies have shown that post-nesting turtles tagged in Mexico and Central America migrated southward into the Southern Hemisphere (Dutton et al. 2006). Female leatherback turtles tagged at a nesting site in Costa Rica migrated southwest along a well-defined corridor, past the Galápagos Islands, then dispersed into the oligotrophic gyre of the eastern South Pacific south of 10°S (Palacios et al. 2010; Shillinger et al. 2010). After dispersal, the turtles were found between 10°N and 40°S, from 130°W to the coast of Central and South America (Palacios et al. 2010; Shillinger et al. 2010). Leatherback turtles likely migrate to high productivity areas associated with increased availability of food sources (Shillinger et al. 2011; Bailey et al. 2012a).

Tag returns, genetic analyses, and satellite telemetry data suggest that leatherback turtles in the southeast Pacific Ocean off the coast of Chile belong primarily to the depleted East Pacific nesting stock, which has declined to near extinction (Shillinger et al. 2008; Donoso and Dutton 2010). A small number of leatherback turtles fitted with satellite transmitters in Mexico and Costa Rica have been recorded in waters far offshore (>370 km) from Chile as far south as 37.6°S (Shillinger et al. 2008, 2011; Bailey et al. 2012a,b). Size estimates of leatherback turtles found in Chilean waters indicate that most individuals are juveniles or sub-adults (Sarmiento-Devia et al. 2015).

The leatherback turtle is the most abundant sea turtle species in Chile (Brito 1998). Records of leatherback turtles from Chilean waters are almost entirely of individuals captured as bycatch from industrial or artisanal fisheries (Sarmiento-Devia et al. 2015). A literature review of leatherback records (strandings, bycatch, and sightings) for Chile up to December 2013 yielded 607 leatherback records for Chile, most of which (569) were bycatch; most records were reported for January–March, with fewer sightings from April–November. Very few records were reported north of 33°S (Sarmiento-Devia et al. 2015); most records occurred near the southern end (~33.2°S) of the central proposed survey area. There were also several records from Bío Bío and Los Rios in the latitudinal range of the southern proposed survey area. Similarly, during the Chilean industrial longline fishery for swordfish during February–December 2001–2005, leatherbacks were the most frequently caught turtle (n = 284) in International Waters throughout the year; most were captured between 24°S and 38°S (Donoso and Dutton 2010). However, during shore-based and onboard observer programs from three artisanal fisheries ports in Peru, leatherback turtles were the least common sea turtle species encountered (Alfaro-Shigueto et al. 2011).

This is likely because leatherback turtles are highly pelagic, and small-scale fisheries operate primarily along the coast (Alfaro-Shigueto et al. 2011). Alfaro-Shigueto et al. (2012) reported two interactions of leatherbacks with fishing vessels during January 2009–December 2010 within the northern proposed survey area and one just to the southwest at ~24°S, 74°W.

There are 21 records of leatherback turtles in the SIBIMAP database for Chile (CPPS 2015), including one in the northern proposed survey area, one near the border between Chile and Peru, and the remainder between ~26°S and 39°S, with several in and around the central and southern proposed survey areas. There are no records of leatherback turtles in the OBIS database within the proposed survey areas, but many records from satellite tracking studies exist offshore of these areas (OBIS 2015). The closest records to the proposed survey areas were reported for 27.5°S, 70.5°W and 39.5°S, 72.5°W (Coyne and Godley 2005 *in* OBIS 2015).

3.4.2 Loggerhead Turtle (*Caretta caretta*)

The loggerhead is a widely distributed species, occurring in coastal tropical and subtropical waters of the Atlantic, Pacific, and Indian oceans (Dodd 1988). In the Pacific Ocean, nesting is limited to the western region, mainly Japan and Australia (Conant et al. 2009). Turtles from nesting sites in Australia are known to forage off Chile and Peru (Donoso et al. 2000; Alfaro-Shigueto et al. 2004, 2008; Donoso and Dutton 2006; Boyle et al. 2009). Telemetry studies indicate that some loggerhead turtles are resident in the waters off Peru and northern Chile, which appear to be an important foraging area (Mangel et al. 2010, 2011). Migration of juveniles between coastal Peruvian waters and Chilean oceanic waters has also been documented; one tagged juvenile moved into the northern proposed survey area (Mangel et al. 2011).

Loggerhead turtles have been reported as bycatch in commercial and artisanal longline fisheries in oceanic waters off northern and central Chile and southern Peru (e.g., Alfaro-Shigueto et al. 2008; Donoso and Dutton 2010; Sarmiento-Devia et al. 2015). During the Chilean industrial longline fishery for swordfish during February–December 2001–2005, loggerheads were the second most frequently caught turtle (n = 59) in International Waters; most were taken between 24.3°S and 25.5°S during March (Donoso and Dutton 2010). Similarly, based on a literature review of loggerhead strandings, bycatch, and sightings for Chile up to December 2013, 81 of 86 loggerhead records were of bycatch (Sarmiento-Devia et al. 2015).

Loggerhead turtles were the most common sea turtle species encountered during shore-based and onboard observer programs from three artisanal fisheries ports in Peru (Alfaro-Shigueto et al. 2011). Alfaro-Shigueto et al. (2008) reported numerous records of bycatch by Peruvian fishing operations since 2000 for the waters off Peru and northern Chile, including records within the northern proposed survey area. Alfaro-Shigueto et al. (2012) also reported one interaction of a loggerhead with a fishing vessel during January 2009–December 2010 within the northern proposed survey area and one interaction to the southwest near 22.5°S, 74°W.

There are no records of loggerhead turtles in the SIBIMAP database for Chile (CPPS 2015). There is only one record of a loggerhead turtle in the OBIS database within the northern proposed survey area at 19.5°S, 71.5°W (Mangel et al. 2011 *in* OBIS 2015). Other geolocations from that satellite tracking study are just west and northwest of the northern proposed survey area. There are no records for the central and southern proposed survey areas (OBIS 2015).

3.4.3 Olive Ridley Turtle (*Lepidochelys olivacea*)

The olive ridley turtle has a large range in tropical and subtropical regions in the Pacific, Indian, and South Atlantic oceans (NMFS 2014). In the eastern Pacific, olive ridley turtles range from California to Chile, but are most common off the coasts of Mexico and Central America, where they nest (NMFS 2014). Nesting has also been reported as far south as Peru; olive ridleys occur along the entire coast of Peru, but are more common in the northern regions (Kelez et al. 2009).

Olive ridley turtles do not migrate to any specific foraging grounds but exhibit a nomadic movement pattern (Plotkin et al. 1994; Plotkin 2010). In the ETP, olive ridleys are highly migratory, spending most of their time during the non-breeding season in pelagic waters (Plotkin 2010). In oceanic waters of the east Pacific, olive ridleys are often observed near flotsam, possibly feeding on associated invertebrates and fish (Pitman 1992).

Olive ridley turtles from Chilean waters have been associated with nesting populations in Mexico, Central America, and Columbia (Eckert and Sarti 1997; Velez-Zuazo and Kelez 2010). Limited records of olive ridley turtles suggest that their presence in Chilean waters is seasonal, perhaps coinciding with their occurrence in southern Peru during December–February (Sarmiento-Devia et al. 2015). Sarmiento-Devia et al. (2015) reported 139 olive ridley turtle records for Chile up to December 2013, including offshore bycatch, strandings, and nearshore sightings, with most records for northern Chile in an area of warm water discharge from a power plant near 23.7°S. Other locations with several records were Valparaiso, near the southern end of the central proposed survey area, and Bío Bío, in the latitudinal range of the southern proposed survey area. Most records were reported for March, with fewer records for May–February (Sarmiento-Devia et al. 2015). During shore-based and onboard observer programs from three artisanal fisheries ports in Peru, olive ridley turtles were the third most common sea turtle species encountered (Alfaro-Shigueto et al. 2011). No olive ridley turtles were identified in the longline bycatch off the coast of Chile between 2001 and 2005 (Donoso and Dutton 2010).

There are 2 records of olive ridley turtles in the SIBIMAP database for Chile, but no georeferenced information is available (CPPS 2015). There are no records in the OBIS database for the proposed survey areas (OBIS 2015). The closest record is at 9.36°S, 79.06°W (Kinzey et al. 2001 *in* OBIS 2015); other records are substantially farther north.

3.4.4 Green Turtle (*Chelonia mydas*)

The green turtle is widely distributed in tropical and subtropical waters near continental coasts and around islands. In the east Pacific, it ranges from California at ~42°N to central Chile at 40°S (Seminoff et al. 2015). Nesting occurs widely throughout the eastern Pacific Ocean, but the two primary nesting sites are found in Michoacán, Mexico, and the Galápagos Islands, Ecuador (Seminoff et al. 2015). Smaller nesting aggregations are found in Central America, Columbia, Ecuador, and Peru (Seminoff et al. 2015). There are multiple records of tagged green turtles from the Galápagos Islands being subsequently recaptured off the coasts of Peru and Chile (Brito 1998; Seminoff et al. 2015).

In Chile, green turtles are distributed in bays and along the north coast (Sarmiento-Devia et al. 2015). Green turtles have been reported between the northern and central proposed survey areas, from 21°S to 26°S (Guerra-Correa et al. 2008; Donoso and Dutton 2010). Based on a literature review of records (bycatch, strandings, and nearshore sightings) up to December 2013, Sarmiento-Devia et al. (2015) reported 765 green turtle records for Chile, with most records for northern Chile in an area of warm water discharge from a power plant near 23.7°S. Other locations with several records were

Valparaiso, near the southern end of the central proposed survey area, and Bío Bío and Los Lagos, in the latitudinal range of the southern proposed survey area. Most records were reported for February, with fewer records for March–July and December–January (Sarmiento-Devia et al. 2015). Five green turtles were identified in the commercial longline bycatch in International Waters off the coast of Chile between 2001 and 2005 (Donoso and Dutton 2010). Alfaro-Shigueto et al. (2012) also reported one interaction of a green turtle with a fishing vessel during January 2009–December 2010 just southwest of the northern proposed survey area, near 24°S, 74°W. During shore-based and onboard observer programs from three artisanal fisheries ports in Peru, green turtles were the second most common sea turtle species encountered, likely because small-scale fisheries operate primarily along the coast (Alfaro-Shigueto et al. 2011).

There are 9 records of green turtles in the SIBIMAP database for Chile, but georeferenced information is only available for one; that record occurs near Iquique in the northern proposed survey area (CPPS 2015). There are no records in the OBIS database anywhere near the proposed survey areas (OBIS 2015). The closest sighting is in northern Peru at 4.22°S, 81.18°W (Diveboard *in* OBIS 2015).

3.5 Seabirds

The Humboldt penguin may occur in the proposed survey areas; it is listed as ***Threatened*** under the ESA and *Vulnerable* on the IUCN Red List of Threatened Species (IUCN 2015). General information on the taxonomy, ecology, distribution and movements, and acoustic capabilities of seabird families are given in § 3.5.1 of the PEIS.

3.5.1 Humboldt Penguin (*Spheniscus humboldti*)

Humboldt penguins occur along the west coast of South America, from 5ºS to 42ºS in Peru and Chile. They breed in small colonies on islands or along rocky coastlines (Martinez et al. 2014). A census conducted in Chile during 2001–2008 yielded an average of 33,284 penguins (Wallace and Araya 2015). Threats to the population include mortality from entanglement in fishing nets, loss of habitat because of guano harvesting, and extreme fluctuations in food supply during El Niño years (BirdLife International 2015).

Humboldt penguins likely would be encountered in all of the proposed survey areas, although the waters of northern Chile are considered an area of low penguin abundance (Vianna et al. 2014). Breeding takes place year-round, but peak breeding activity occurs in spring and autumn (Martinez et al. 2014). During the breeding season, the penguins forage close to the colonies; satellite-tracked penguins were found within 35 km of the colony 90% of the time (Culik and Luna-Jorquera 1997). Humboldt penguins are therefore most likely to be encountered when close to breeding colonies. There are numerous breeding sites along the coast of Chile adjacent to the central proposed survey area, including Isla Pájaro Niño (33.4ºS), Islote Concón (32.9ºS), Islote Cachagua (32.6ºS), Islote Papudo (32.5ºS), and Isla de los Huevos (31.9ºS); breeding sites adjacent to the northern proposed survey area include Guanillos Islets (21.7ºS), Punta Patache (20.8ºS), Patillo Islet (20.7ºS), Punta Pierna Gorda and Cueva del Caballo (20.1ºS), as well as a number of islands and headlands in the Santa Rosa area at 19.3ºS (Araya et al. 2000; Wallace and Araya 2015). There are two colonies adjacent to the southern proposed survey area: Islote Pupuya (34.0ºS) and Islote Puñihuil (41.9ºS) (Araya et al. 2000).

3.6 Marine Fish

There is one marine fish species listed under the ESA as ***Endangered*** that could occur in or near the proposed survey areas: the Eastern Pacific DPS of the scalloped hammerhead shark. In addition, there are five marine fish species that are ***candidate species*** for ESA listing: common thresher shark, bigeye thresher shark, porbeagle shark, smooth hammerhead shark, and greytail skate (NMFS 2015a). On the IUCN Red List of Threatened Species (IUCN 2015), the eastern central/southeast Pacific subpopulations of scalloped hammerhead shark are listed as *Endangered*, the eastern central Pacific population of common thresher shark is listed as *Near Threatened*, the eastern central Pacific population of bigeye thresher shark is listed as *Vulnerable*, the porbeagle and smooth hammerhead sharks are listed as *Vulnerable*, and the greytail skate is listed as *Endangered*. The ESA-listed and candidate species are described below. There are no ESA-listed or candidate marine invertebrate species that could occur in the proposed survey areas (NMFS 2015a).

3.6.1 Scalloped Hammerhead Shark (*Sphyrna lewini*)

The scalloped hammerhead shark inhabits warm temperate and tropical waters (Maguire et al. 2006; Miller et al. 2014; NMFS 2015c) and may occur in the northern proposed survey area. It occurs in coastal and estuarine waters, but is also known to inhabit open water over continental and insular shelves, as well as deeper waters, with depths up to 1000 m (Miller et al. 2014; NMFS 2015c). Reproduction occurs annually, with a gestation time of 9–12 months (Kotas 2005). Females move inshore to give birth to litters of 1–41 pups (Miller et al. 2014). The scalloped hammerhead shark is very mobile and partly migratory (Maguire et al. 2006), traveling <100 km to >1900 km between aggregations of food sources, eventually returning to its original habitat, displaying site fidelity (Miller et al. 2014). Juveniles and adults can be solitary or travel in pairs; they also school in productive regions, such as over seamounts or near islands (Miller et al. 2014).

3.6.2 Common Thresher Shark (*Alopias vulpinus*)

The common thresher shark is a cosmopolitan species that is found in temperate, subtropical, and tropical waters, but it is most common in temperate waters (Compagno 2001). Thus, it may occur in the northern, central, or southern proposed survey areas. It mainly inhabits coastal areas, from the surface to depths of up to 366 m, but it can also occur in oceanic areas (Compagno 2001). Nursery areas apparently are found primarily nearshore in temperate waters (Compagno 2001). Females have litters of 2–7 young that are born in spring after a gestation period of ~9 months (Compagno 2001). Young thresher sharks typically remain inshore and in shallow bays (Compagno 2001).

3.6.3 Bigeye Thresher Shark (*Alopias supercilious*)

The bigeye thresher shark occurs in temperate and tropical oceans worldwide (Compagno 2001) and may be found in the northern proposed survey area. It occurs at depths up to at least 500 m (Compagno 2001). It undergoes diel vertical migration, spending the daytime in deeper water and rising up into the water column to feed at night (Weng and Block 2004). The bigeye thresher shark is an epibenthic and epipelagic predator that stuns its prey with its long caudal fin before feeding. It is ovoviviparous with litters of usually two, but upwards of four pups. It is caught commonly in longlines (Compagno 2001).

3.6.4 Porbeagle Shark (*Lamna nasus*)

The porbeagle shark inhabits coastal and oceanic waters in temperate regions of the Northern and Southern hemispheres (Compagno 2001) and may be found in the central and southern proposed survey areas. It is a littoral and epipelagic species that primarily occurs on continental offshore fishing banks, but it is also found in oceanic basins and nearshore waters; its depth range is from <1 m to at least 700 m (Compagno 2001). It can occur inshore and near the surface during summer, but it tends to remain offshore, beneath the surface during winter. Some populations, such as those in the western North Atlantic, are highly migratory, typically traveling thousands of kilometers along continental shelves

(Compagno 2001). Litter size is 1–5 pups (usually 4) with pups born from April to September in the Southern Hemisphere (Compagno 2001). Reproduction is annual with an 8–9 month gestation period (Stevens 2005).

3.6.5 Smooth Hammerhead Shark (*Sphyrna zygaena*)

The smooth hammerhead shark is found in tropical and temperate seas worldwide, and may occur in the northern, central, and southern proposed survey areas. It is found on the continental shelf as well as bays and estuaries. It prefers to stay close to the surface, mainly inhabiting 20-m depths; however, it has been known to inhabit waters as deep as 200 m (Ebert 2003). The gestation period is 10–11 months (Ebert 2003), and females give birth to live young with litters of 29–37 pups (Compagno 1998). Young sharks are often found in large aggregations of hundreds of individuals. During summer, individuals migrate to cooler water, returning in winter to equatorial regions (Ebert 2003).

3.6.6 Greytail Skate (*Bathyraja griseocauda*)

The greytail skate is found in the southeast Pacific and the southwest Atlantic, including off the coast of Chile (AquaMaps 2015); thus, it may occur in the southern proposed survey area. It is a benthic species commonly found in water depths of 82–941 m, in bottom temperatures 3–8°C (Menni and Stehmann 2000). Off Chile, it occurs at depths of 137–595 m (J. Lamilla pers. comm. 2006 *in* NMFS 2015d). It is a slow-growing, late-maturing, and long-lived species (Wakeford et al. 2005). Individuals mature at ~15 years of age. Females are oviparous and lay paired eggs (Dulvy and Reynolds 1997).

3.7 Fisheries

Fisheries in Chile consist of large-scale commercial and small-scale artisanal fisheries. Aquaculture is also an economically important activity. Commercial and artisanal fisheries use different sizes of fishing vessel. As defined in the 1991 *Chilean Fishery and Aquaculture Law*, the artisan fleet has a maximum vessel length of 18 m and 50 gross tons, and the industrial fleet includes vessels >50 gross tons; vessels in the artisan fleet are usually <8–10 m long (Castilla 2010). Chile's overall fisheries landings were the seventh largest in the world in 2010 (OECD 2013). Most of the total fish landings is used as raw material for the production of fishmeal that is exported to foreign markets or used in Chile's aquaculture programs. The rest of the catches are made up of crustacean and mollusc species of high commercial value in the world market (FAO 2015a).

Following a period of severe overfishing, Chile set up a quota system in 2001, which helped stocks stabilize. In December 2013, a new fisheries law was established that considers several measures for fisheries recovery, such as quotas being recommended by scientists instead of fisheries stakeholders. Further, management committees have been formed that establish new administration measures for the recovery of overexploited fisheries. The new law also requires artisanal fishers to have satellite vessel monitoring systems (VMS) on board their vessels (van der Meer et al. 2015). Some of the main enforcement measures include a total allowable catch regulation for all main fisheries, maximum catch limit per vessel owner (for industrial fisheries), individual transferable quota, and small-scale extraction regimes for specific artisanal fisheries. There are also limits to the number of vessel licenses (for industrial and artisanal fisheries), restrictions on the number of vessels per operator, and restrictions on fishing gear. Biological management measures include minimum legal size of catch, restrictions on sex catch (for crustacean fisheries), and a maximum percentage of bycatch. There are also time closures for specific fisheries and area regulations, i.e., restricted fishing in marine reserves and parks (OECD 2013).

3.7.1 Commercial Fisheries

Chile has a multi-gear and multi-species commercial fishery that included ~254 vessels in 2013 (FAO 2015a). In the industrial fishery sector, small pelagic species are most commonly targeted using a midwater trawl or purse seine; crustaceans such as prawn and shrimp are fished using bottom trawls, and large pelagics such as swordfish and tuna are taken with longlines (van der Meer et al. 2015). Reconstructed catch information using a combination of official reported data and reconstructed estimates of unreported data (including major discards) completed by the Sea Around Us Project (SAUP) indicates that the industrial fishery sector landed ~2.1 million tons of fish in 2012 (van der Meer et al. 2015).

In Chile, pelagic fisheries are concentrated around major upwelling centers at 20–22°S, 32–34°S, and 36–38°S (Thiel et al. 2007). In the northern regions, anchovies account for most of the landings, followed by jack mackerel and American mackerel (OECD 2009 *in* van der Meer et al. 2015); the largest quantities of mackerel and sardines are caught in central and southern Chile. Most (~80%) of these industrial landings are processed to produce fishmeal and fish oil for salmon aquaculture with the rest exported to foreign countries (van der Meer et al. 2015). Overall, the predominant species caught in Chilean EEZ waters include Chilean jack mackerel *Trachurus murphyi*, anchoveta *Engraulis ringens*, South American pilchard *Sardinops sagax*, Araucanian herring *Clupea bentincki*, South Pacific hake *Merluccius gayi gayi*, Falkland sprat *Sprattus fuegensis*, Patagonian grenadier *Macruronus magellanicus*, chub mackerel *Scomber japonicus*, yellow prawn *Cervimunida johni*, red prawn *Pleuroncodes monodon*, nylon shrimp *Heterocarpus reedi*, Patagonia toothfish *Dissostichus eleginoides*, eels Ophichthidae; and swordfish *Xiphias gladius* (OECD 2013; van der Meer et al. 2015).

3.7.2 Artisanal Fisheries

Artisanal fishing is practiced all along Chile’s 6435-km coastline and combines industrial techniques with pre-Hispanic traditions. In 2013, the artisanal fishing fleet consisted of ~12,700 fishing boats (FAO 2015a). Artisanal fishers land their products in coastal villages or at wharfs, most of the latter located in rural areas where most livelihoods depend directly on fishing (CENDEC 2010 *in* van der Meer et al. 2015). Artisanal fisheries primarily target giant kelp, sardine and anchovy, invertebrates such as Chilean abalone, giant squid, king crab, sea urchin, clams, and different species of demersal fish (OECD 2013). Most of the artisanal landings are used for local consumption, with some sold to seafood exporters.

Artisanal fishers are required to register with the National Registry of Artisanal Fisheries (NRAF) in the particular area where they reside and can only operate in that area. They are allocated exclusive rights to waters up to 9.3 km from shore (OECD 2013; FAO 2015a; van der Meer et al. 2015); this area is called the artisan exclusive zone (AEZ), which covers ~27,000 km^2 between 18.35°S and 41.5°S (Castilla 2010). There are no fisheries zoning restrictions for industrial or artisanal fishing fleets south of there.

Reconstructed catch information completed by SAUP indicates that the artisanal fishery sector landed ~1.0 million tons of fish in 2012 (van der Meer et al. 2015). Overall, the reconstructed total catch was composed of anchovy (28%), Chilean jack mackerel (26%), South American pilchard (19%), and Araucanian herring (8.3%). Other species that had a significant contribution to the catch included chub mackerel, jumbo squid *Dosidicus gigas*, snake eels *Ophichthus* spp., yellow prawn, bacaladillo *Normanichthys crockeri*, Chilean sea urchin *Loxechinus albus*, and red prawn (van der Meer et al. 2015).

3.7.3 Recreational Fisheries

Sport fishing is popular in both freshwater and marine environments in Chile. It is practiced in rivers, lakes, dams, reservoirs, and in the sea from either the shore or boats. Recreational fishing can be divided into four types: release fishing or spinning, fly fishing, catch and release, and trolling (FAO 2015a). Species targeted in the marine recreational fisheries include sole, tuna, and sea bass. Salmon are typically fished in estuaries along the central and southern regions in Chile. The recreational fisheries industry is managed and regulated by Chile's National Fisheries Service (SERNAPESCA) and the Undersecretariat of Fisheries (SUBPESCA), who regulate and oversee the use of gear and equipment, limits on fishing seasons, catch quotas and catch size, and the number of fishing licenses available to local residents and foreign visitors (OECD 2013; FAO 2015a).

3.7.3 Aquaculture

Aquaculture in Chile is mainly geared toward the production of fish, molluscs, and algae for international markets. In 2012, aquaculture production reached over 1.1 million tonnes (OECD 2015). Aquaculture in Chile takes place mainly in coastal marine environments with some aquaculture occurring in rivers and lakes. The main cultivation systems used are floating cages for fish farming and breeding lines (long-lines) for shellfish farming. There are at least 14 species that are grown commercially (FAO 2015b) including fish such as Atlantic salmon *Salmo salar*, Pacific coho salmon *Oncorhynchus kisutch*, king salmon *Oncorhynchus tschawyscha*, rainbow trout *Oncorhynchus mykiss*, and turbot *Psetta maxima*; invertebrates such as Chilean oyster *Ostrea chilensis*, Pacific oyster *Crassostrea gigas*, northern scallop *Argopecten purpuratus*, choro *Choromytilus chorus*, chorito *Mytilus chilensis*, cholga *Aulacomya ater*, red abalone *Haliotis rufescens*, and Japanese abalone *Haliotis discus hannai*; and red algae *Gracilaria*. Sepúlveda et al. (2015b) noted the presence of salmon farms in the Gulf of Ancud.

3.8 Recreational SCUBA Diving

Scuba diving occurs year-round in Chile, with a peak diving period between September and May (Wanna Dive 2015). Northern Chile is popular for diving as the warm (~16–20°C) waters are home to abundant and diverse marine life and corals. Southern Chile has cooler (~12–13°C) waters with good visibility that are home to seal and sea lion colonies, dolphins, and whales (Dive Advisor 2015). Easter Island and the Juan Fernández Islands are also popular dive locations. A search of diving websites including Scuba Earth (www.scubaearth.com), Dive Advisor (www.diveadvisor.com), Wanna Dive (www.wannadive.net), Diveboard (www.diveboard.com), and others indicate minimal to no scuba diving north of the city of Iquique in the Tarapaca region, northern Chile. Some scuba diving could occur in the proposed survey areas south of Iquique, particularly near the shallowest portions of the southern proposed survey area; one dive site at ~42.2ºS, 74.3ºW is located ~8 km east of the southern proposed survey area (Diveboard 2015). The central proposed survey area is far enough offshore that potential interactions with divers are unlikely.

Non-recreational SCUBA diving in depths up to 100 m may occur near the shallow portions of the southern proposed survey area; these dives would be conducted by Chilean Navy divers, for the potential purposes of body rescues, explorations, inspections, and reconnaissance for material loss (Diálogo 2015a), or by specialized marine companies serving Chile, such as Resolve Marine Group Inc., which is based in the U.S. (Environmental XPRT 2015).

IV ENVIRONMENTAL CONSEQUENCES

4.1 Proposed Action

4.1.1 Direct Effects on Marine Mammals and Sea Turtles and Their Significance

The material in this section includes a brief summary of the expected potential effects (or lack thereof) of airgun sounds on marine mammals and sea turtles given in the PEIS, and reference to recent literature that has become available since the PEIS was released in 2011. A more comprehensive review of the relevant background information, as well as information on the hearing abilities of marine mammals and sea turtles, appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

This section also includes estimates of the numbers of marine mammals that could be affected by the proposed seismic surveys. A description of the rationale for NSF's estimates of the numbers of individuals exposed to received sound levels ≥160 dB re 1 μPa_{rms} is also provided. Acoustic modeling for the Proposed Action was conducted by L-DEO, consistent with past EAs and determined to be acceptable by NMFS for use in the calculation of estimated takes under the MMPA (e.g., NMFS 2013a,b).

4.1.1.1 Summary of Potential Effects of Airgun Sounds

As noted in the PEIS (§ 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3), the effects of sounds from airguns could include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and at least in theory, temporary or permanent hearing impairment, or non-auditory physical or physiological effects (Richardson et al. 1995; Gordon et al. 2004; Nowacek et al. 2007; Southall et al. 2007). In some cases, a behavioral response to a sound can reduce the overall exposure to that sound (e.g., Finneran et al. 2015; Wensveen et al. 2015).

Permanent hearing impairment (PTS), in the unlikely event that it occurred, would constitute injury, but temporary threshold shift (TTS) is not considered an injury (Southall et al. 2007; Le Prell 2012). Rather, the onset of TTS has been considered an indicator that, if the animal is exposed to higher levels of that sound, physical damage is ultimately a possibility. Nonetheless, recent research has shown that sound exposure can cause cochlear neural degeneration, even when threshold shifts and hair cell damage are reversible (Liberman 2013). These findings have raised some doubts as to whether TTS should continue to be considered a non-injurious effect (Weilgart 2014; Tougaard et al. 2015). Although the possibility cannot be entirely excluded, it is unlikely that the proposed survey would result in any cases of temporary or permanent hearing impairment, or any significant non-auditory physical or physiological effects. If marine mammals encounter the survey while it is underway, some behavioral disturbance could result, but this would be localized and short-term.

***Tolerance*.—**Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers (e.g., Nieukirk et al. 2012). Several studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response. That is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen and toothed whales, and (less frequently) pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. The relative responsiveness of baleen and toothed whales are quite variable.

***Masking*.—**Masking effects of pulsed sounds (even from large arrays of airguns) on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Because of the intermittent nature and low duty cycle of seismic pulses, animals can emit and receive sounds in the relatively quiet intervals between pulses. However, in exceptional situations, reverberation occurs for much or all of the interval between pulses (e.g., Simard et al. 2005; Clark and Gagnon 2006), which could mask calls. Situations with prolonged strong reverberation are infrequent. However, it is common for reverberation to cause some lesser degree of elevation of the background level between airgun pulses (e.g., Gedamke 2011; Guerra et al. 2011, 2013; Klinck et al. 2012; Guan et al. 2015), and this weaker reverberation presumably reduces the detection range of calls and other natural sounds to some degree. Guerra et al. (2013) reported that ambient noise levels between seismic pulses were elevated as a result of reverberation at ranges of 50 km from the seismic source. Based on measurements in deep water of the Southern Ocean, Gedamke (2011) estimated that the slight elevation of background levels during intervals between pulses reduced blue and fin whale communication space by as much as 36–51% when a seismic survey was operating 450–2800 km away. Based on preliminary modeling, Wittekind et al. (2013) reported that airgun sounds could reduce the communication range of blue and fin whales 2000 km from the seismic source. Nieukirk et al. (2012) and Blackwell et al. (2013) noted the potential for masking effects from seismic surveys on large whales.

Some baleen and toothed whales are known to continue calling in the presence of seismic pulses, and their calls usually can be heard between the pulses (e.g., Nieukirk et al. 2012; Broker et al. 2013). Cerchio et al. (2014) suggested that the breeding display of humpback whales off Angola could be disrupted by seismic sounds, as singing activity declined with increasing received levels. In addition, some cetaceans are known to change their calling rates, shift their peak frequencies, or otherwise modify their vocal behavior in response to airgun sounds (e.g., Di Iorio and Clark 2010; Castellote et al. 2012; Blackwell et al. 2013, 2015). The hearing systems of baleen whales are undoubtedly more sensitive to low-frequency sounds than are the ears of the small odontocetes that have been studied directly (e.g., MacGillivray et al. 2014). The sounds important to small odontocetes are predominantly at much higher frequencies than are the dominant components of airgun sounds, thus limiting the potential for masking. In general, masking effects of seismic pulses are expected to be minor, given the normally intermittent nature of seismic pulses. We are not aware of any information concerning masking of hearing in sea turtles.

***Disturbance Reactions*.—**Disturbance includes a variety of effects, including subtle to conspicuous changes in behavior, movement, and displacement. Based on NMFS (2001, p. 9293), National Research Council (NRC 2005), and Southall et al. (2007), we believe that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean, 'in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations'.

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors (Richardson et al. 1995; Wartzok et al. 2004; Southall et al. 2007; Weilgart 2007; Ellison et al. 2012). If a marine mammal does react briefly to an underwater sound by changing its behavior or moving a small distance, the impacts of the change are unlikely to be significant to the individual, let alone the stock or population (e.g., New et al. 2013). However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on individuals and populations could be significant (Lusseau and Bejder 2007; Weilgart 2007; Nowacek et al. 2015). Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many marine mammals would be present within a particular distance of industrial activities and/or exposed to a particular level of industrial sound. In most cases, this approach likely overestimates the numbers of marine mammals that would be affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals could be disturbed to some biologically important degree by a seismic program are based primarily on behavioral observations of a few species. Detailed studies have been done on humpback, gray, bowhead, and sperm whales. Less detailed data are available for some other species of baleen whales and small toothed whales, but for many species, there are no data on responses to marine seismic surveys.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to pulses from large arrays of airguns at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the cases of migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors (Malme et al. 1984; Malme and Miles 1985; Richardson et al. 1995).

Responses of *humpback whales* to seismic surveys have been studied during migration, on summer feeding grounds, and on Angolan winter breeding grounds; there has also been discussion of effects on the Brazilian wintering grounds. Off Western Australia, avoidance reactions began at 5–8 km from the array, and those reactions kept most pods ~3–4 km from the operating seismic boat; there was localized displacement during migration of 4–5 km by traveling pods and 7–12 km by more sensitive resting pods of cow-calf pairs (McCauley et al. 1998, 2000). However, some individual humpback whales, especially males, approached within distances of 100–400 m. Studies examining the behavioral responses of humpback whales to airguns are currently underway off eastern Australia (Cato et al. 2011, 2012, 2013).

In the northwest Atlantic, sighting rates were significantly greater during non-seismic periods compared with periods when a full array was operating, and humpback whales were more likely to swim away and less likely to swim towards a vessel during seismic vs. non-seismic periods (Moulton and Holst 2010). In contrast, sightings of humpback whales from seismic vessels off the U.K. during 1994–2010 indicated that detection rates were similar during seismic and non-seismic periods, although sample sizes were small (Stone 2015). On their summer feeding grounds in southeast Alaska, there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis (Malme et al. 1985). It has been suggested that South Atlantic humpback whales wintering off Brazil may be displaced or even strand upon exposure to seismic surveys (Engel et al. 2004), but data from subsequent years indicated that there was no observable direct correlation between strandings and seismic surveys (IWC 2007b).

There are no data on reactions of *right whales* to seismic surveys. However, Rolland et al. (2012) suggested that ship noise causes increased stress in right whales; they showed that baseline levels of stress-related faecal hormone metabolites decreased in North Atlantic right whales with a 6-dB decrease in underwater noise from vessels. Wright et al. (2011) and Atkinson et al. (2015) also reported that sound could be a potential source of stress for marine mammals.

Bowhead whales show that their responsiveness can be quite variable depending on their activity (migrating vs. feeding). Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn, in particular, are unusually responsive, with substantial avoidance occurring out to distances of 20–30 km from a medium-sized airgun source (Miller et al. 1999; Richardson et al. 1999). Subtle but statistically significant changes in surfacing–respiration–dive cycles were shown by traveling and socializing bowheads exposed to airgun sounds in the Beaufort Sea, including shorter surfacings, shorter dives, and decreased number of blows per surfacing (Robertson et al. 2013). More recent research on bowhead whales corroborates earlier evidence that, during the summer feeding season, bowheads are less responsive to seismic sources (e.g., Miller et al. 2005; Robertson et al. 2013).

Bowhead whale calls detected in the presence and absence of airgun sounds have been studied extensively in the Beaufort Sea. Bowheads continue to produce calls of the usual types when exposed to airgun sounds on their summering grounds, although numbers of calls detected are significantly lower in the presence than in the absence of airgun pulses (Blackwell et al. 2013, 2015). Blackwell et al. (2013) reported that calling rates in 2007 declined significantly where received SPLs from airgun sounds were 116–129 dB re 1 μPa; at SPLs <108 dB re 1 μPa, calling rates were not affected. When data for 2007–2010 were analyzed, Blackwell et al. (2015) reported an initial increase in calling rates when airgun pulses became detectable; however, calling rates leveled off at a received $CSEL_{10\text{-min}}$ (cumulative SEL over a 10-min period) of ~94 dB re 1 $\mu Pa^2 \cdot s$, decreased at $CSEL_{10\text{-min}}$ >127 dB re 1 $\mu Pa^2 \cdot s$, and whales were nearly silent at $CSEL_{10\text{-min}}$ >160 dB re 1 $\mu Pa^2 \cdot s$. Thus, bowhead whales in the Beaufort Sea apparently decreased their calling rates in response to seismic operations, although movement out of the area could also have contributed to the lower call detection rate (Blackwell et al. 2013, 2015).

A multivariate analysis of factors affecting the distribution of calling bowhead whales during their fall migration in 2009 noted that the southern edge of the distribution of calling whales was significantly closer to shore with increasing levels of airgun sound from a seismic survey a few hundred kilometers to the east of the study area (i.e., behind the westward-migrating whales; McDonald et al. 2010, 2011). It was not known whether this statistical effect represented a stronger tendency for quieting of the whales farther offshore in deeper water upon exposure to airgun sound, or an actual inshore displacement of whales.

Reactions of migrating and feeding (but not wintering) *gray whales* to seismic surveys have been studied. Off St. Lawrence Island in the northern Bering Sea, it was estimated, based on small sample sizes, that 50% of feeding gray whales stopped feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB re 1 μPa_{rms} (Malme et al. 1986, 1988). Those findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast (Malme et al. 1984; Malme and Miles 1985) and western Pacific gray whales feeding off Sakhalin Island, Russia (e.g., Gailey et al. 2007; Johnson et al. 2007; Yazvenko et al. 2007a,b).

Various species of *Balaenoptera* (blue, sei, fin, and minke whales) have occasionally been seen in areas ensonified by airgun pulses. Sightings by observers on seismic vessels using large arrays off the U.K. from 1994 to 2010 showed that the detection rate for minke whales was significantly higher when airguns were not operating; however, during surveys with small arrays, the detection rates for minke whales were similar during seismic and non-seismic periods (Stone 2015). Sighting rates for fin and sei whales were similar when large arrays of airguns were operating vs. silent (Stone 2015). All baleen whales combined tended to exhibit localized avoidance, remaining significantly farther (on average) from large arrays (median closest point of approach or CPA of ~1.5 km) during seismic operations compared with non-seismic periods (median CPA ~1.0 km; Stone 2015). In addition, fin and minke whales were more often oriented away from the vessel while a large airgun array was active compared with periods of inactivity (Stone 2015). Singing fin whales in the Mediterranean moved away from an operating airgun array, and their song notes had lower bandwidths during periods with vs. without airgun sounds (Castellote et al. 2012).

During seismic surveys in the northwest Atlantic, baleen whales as a group showed localized avoidance of the operating array (Moulton and Holst 2010). Sighting rates were significantly lower during seismic operations compared with non-seismic periods. Baleen whales were seen on average 200 m farther from the vessel during airgun activities vs. non-seismic periods, and these whales more often swam away from the vessel when seismic operations were underway compared with periods when no airguns were operating (Moulton and Holst 2010). Blue whales were seen significantly farther from the vessel during single airgun operations, ramp up, and all other airgun operations compared with non-seismic periods (Moulton and Holst 2010). Similarly, fin whales were seen at significantly farther distances during ramp up than during periods without airgun operations; there was also a trend for fin whales to be sighted farther from the vessel during other airgun operations, but the difference was not significant (Moulton and Holst 2010). Minke whales were seen significantly farther from the vessel during periods with than without seismic operations (Moulton and Holst 2010). Minke whales were also more likely to swim away and less likely to approach during seismic operations compared to periods when airguns were not operating (Moulton and Holst 2010).

Data on short-term reactions by cetaceans to impulsive noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales have continued to migrate annually along the west coast of North America with substantial increases in the population over recent years, despite intermittent seismic exploration (and much ship traffic) in that area for decades. The western Pacific gray whale population did not seem affected by a seismic survey in its feeding ground during a previous year, and bowhead whales have continued to travel to the eastern Beaufort Sea each summer, and their numbers have increased notably, despite seismic exploration in their summer and autumn range for many years.

Toothed Whales

Little systematic information is available about reactions of toothed whales to sound pulses. However, there are recent systematic studies on sperm whales, and there is an increasing amount of information about responses of various odontocetes to seismic surveys based on monitoring studies. Seismic operators and marine mammal observers on seismic vessels regularly see dolphins and other small toothed whales near operating airgun arrays, but in general there is a tendency for most delphinids to show some avoidance of operating seismic vessels (e.g., Stone and Tasker 2006; Moulton and Holst 2010; Barry et al. 2012; Wole and Myade 2014; Stone 2015). In most cases, the avoidance radii for delphinids appear to be small, on the order of 1 km or less, and some individuals show no apparent avoidance.

Observations from seismic vessels using large arrays off the U.K. from 1994 to 2010 indicated that detection rates were significantly higher for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins when airguns were not operating; detection rates during seismic vs. non-seismic periods were similar during seismic surveys using small arrays (Stone 2015). Detection rates for long-finned pilot whales, Risso's dolphins, bottlenose dolphins, and short-beaked common dolphins were similar during seismic (small or large array) vs. non-seismic operations (Stone 2015). CPA distances for killer whales, white-beaked dolphins, and Atlantic white-sided dolphins were significantly farther (>0.5 km) from large airgun arrays during periods of airgun activity compared with periods of inactivity, with significantly more animals traveling away from the vessel during airgun operation (Stone 2015). Observers' records suggested that fewer cetaceans were feeding and fewer delphinids were interacting with the survey vessel (e.g., bow-riding) during periods with airguns operating (Stone 2015).

During seismic surveys in the northwest Atlantic, delphinids as a group showed some localized avoidance of the operating array (Moulton and Holst 2010). The mean initial detection distance was significantly farther (by ~200 m) during seismic operations compared with periods when the seismic source was not active; however, there was no significant difference between sighting rates (Moulton and Holst 2010). The same results were evident when only long-finned pilot whales were considered.

Preliminary findings of a monitoring study of *narwhals* in Melville Bay, Greenland (summer and fall 2012) showed no short-term effects of seismic survey activity on narwhal distribution, abundance, migration timing, and feeding habits (Heide-Jørgensen et al. 2013a). In addition, there were no reported effects on narwhal hunting. These findings do not seemingly support a suggestion by Heide-Jørgensen et al. (2013b) that seismic surveys in Baffin Bay may have delayed the migration timing of narwhals, thereby increasing the risk of narwhals to ice entrapment.

The beluga, however, is a species that (at least at times) shows long-distance (10s of km) avoidance of seismic vessels (e.g., Miller et al. 2005). Captive bottlenose dolphins and beluga whales exhibited changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys, but the animals tolerated high received levels of sound before exhibiting aversive behaviors (e.g., Finneran et al. 2000, 2002, 2005).

Most studies of *sperm whales* exposed to airgun sounds indicate that the sperm whale shows considerable tolerance of airgun pulses; in most cases the whales do not show strong avoidance (e.g., Stone and Tasker 2006; Moulton and Holst 2010), but foraging behavior can be altered upon exposure to airgun sound (e.g., Miller et al. 2009). Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates for sperm whales were similar when large arrays of airguns were operating vs. silent; however, during surveys with small arrays, the detection rate was significantly higher when the airguns were not in operation (Stone 2015). Preliminary data from the Gulf of Mexico show a correlation between reduced sperm whale acoustic activity during periods with airgun operations (Sidorovskaia et al. 2014).

There are almost no specific data on the behavioral reactions of *beaked whales* to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998) and/or change their behavior in response to sounds from vessels (e.g., Pirotta et al. 2012). Thus, it is likely that most beaked whales would also show strong avoidance of an approaching seismic vessel. Observations from seismic vessels off the U.K. from 1994 to 2010 indicated that detection rates of beaked whales were significantly higher (p<0.05) when airguns were not operating vs. when a large array was in operation, although sample sizes were small (Stone 2015). Some northern bottlenose whales remained in the general area and continued to produce high-frequency clicks when exposed to sound pulses from distant seismic surveys (e.g., Simard et al. 2005).

The limited available data suggest that *harbor porpoises* show stronger avoidance of seismic operations than do Dall's porpoises. Based on data collected by observers on seismic vessels off the U.K. from 1994 to 2010, detection rates of harbor porpoises were significantly higher when airguns were silent vs. when large or small arrays were operating (Stone 2015). In addition, harbor porpoises were seen farther away from the array when it was operating vs. silent, and were most often seen traveling away from the airgun array when it was in operation (Stone 2015). Thompson et al. (2013) reported decreased densities and reduced acoustic detections of harbor porpoise in response to a seismic survey in Moray Firth, Scotland, at ranges of 5–10 km (SPLs of 165–172 dB re 1 μPa, SELs of 145–151 dB $\mu Pa^2 \cdot s$). For the same survey, Pirotta et al. (2014) reported that the probability of recording a porpoise buzz decreased by 15% in the ensonified area, and that the probability was positively related to the distance from the seismic ship; the decreased buzzing occurrence may indicate reduced foraging efficiency. Nonetheless, animals returned to the area within a few hours (Thompson et al. 2013). Kastelein et al. (2013a) reported that a harbor porpoise showed no response to an impulse sound with an SEL below 65 dB, but a 50% brief response rate was noted at an SEL of 92 dB and an SPL of 122 dB re 1 $\mu Pa_{0\text{-}peak.}$ The apparent tendency for greater responsiveness in the harbor porpoise is consistent with its relative responsiveness to boat traffic and some other acoustic sources (Richardson et al. 1995; Southall et al. 2007).

Odontocete reactions to large arrays of airguns are variable and, at least for delphinids, seem to be confined to a smaller radius than has been observed for the more responsive of the mysticetes and some other odontocetes. A ≥170 dB disturbance criterion (rather than ≥160 dB) is considered appropriate for delphinids, which tend to be less responsive than the more responsive cetaceans.

Pinnipeds

Pinnipeds are not likely to show a strong avoidance reaction to an airgun array. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds and only slight (if any) changes in behavior. However, telemetry work has suggested that avoidance and other behavioral reactions may be stronger than evident to date from visual studies (Thompson et al. 1998). Observations from seismic vessels operating large arrays off the U.K. from 1994 to 2010 showed that the detection rate for grey seals was significantly higher when airguns were not operating; for surveys using small arrays, the detection rates were similar during seismic vs. non-seismic operations (Stone 2015). No significant differences in detection rates were apparent for harbor seals during seismic and non-seismic periods (Stone 2015). There were no significant differences in CPA distances of grey or harbor seals during seismic vs. non-seismic periods (Stone 2015). Lalas and McConnell (2015) made observations of New Zealand fur seals from a seismic vessel operating a 3090 in^3 airgun array in New Zealand during 2009. However, the results from the study were inconclusive in showing whether New Zealand fur seals respond to seismic sounds.

Sea Turtles

Several recent papers discuss the morphology of the turtle ear (e.g., Christensen-Dalsgaard et al. 2012; Willis et al. 2013) and the hearing ability of sea turtles (e.g., Martin et al. 2012; Piniak et al. 2012a,b; Lavender et al. 2014). The limited available data indicate that sea turtles will hear airgun sounds and sometimes exhibit localized avoidance (see PEIS, § 3.4.4.3). In additional, Nelms et al. (2016) suggest that sea turtles could be excluded from critical habitats.

DeRuiter and Doukara (2012) observed that immediately following an airgun pulse, small numbers of basking loggerhead turtles (6 of 86 turtles observed) exhibited an apparent startle response (sudden raising of the head and splashing of flippers, occasionally accompanied by blowing bubbles from the beak and nostrils, followed by a short dive). Diving turtles (49 of 86 individuals) were observed at distances from the center of the airgun array ranging from 50 to 839 m. The estimated sound level at the median distance of 130 m was 191 dB re 1 μPa_{peak}. These observations were made during ~150 h of vessel-based monitoring from a seismic vessel operating an airgun array (13 airguns, 2440 in^3) off Algeria; there was no corresponding observation effort during periods when the airgun array was inactive (DeRuiter and Doukara 2012).

Based on available data, it is likely that sea turtles will exhibit behavioral changes and/or avoidance within an area of unknown size near a seismic vessel. To the extent that there are any impacts on sea turtles, seismic operations in or near areas where turtles concentrate would likely have the greatest impact; concentration areas are not known to occur within the proposed survey areas. There are no specific data that demonstrate the consequences to sea turtles if seismic operations with large or small arrays of airguns occur in important areas at biologically important times of the year.

Hearing Impairment and Other Physical Effects.—Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds. TTS has been demonstrated and studied in certain captive odontocetes and pinnipeds exposed to strong sounds (reviewed by Southall et al. 2007; Finneran 2015). However, there has been no specific documentation of TTS let alone permanent hearing damage, i.e., PTS, in free-ranging marine mammals exposed to sequences of airgun pulses during realistic field conditions.

Additional data are needed to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. To determine how close an airgun array would need to approach in order to elicit TTS, one would (as a minimum) need to allow for the sequence of distances at which airgun pulses would occur, and for the dependence of received SEL on distance in the region of the seismic operation (e.g., Breitzke and Bohlen 2010; Laws 2012). At the present state of knowledge, it is also necessary to assume that the effect is directly related to total received energy (SEL); however, this assumption is likely an over-simplification (Finneran 2012). There is recent evidence that auditory effects in a given animal are not a simple function of received acoustic energy (Finneran 2015). Frequency, duration of the exposure, and occurrence of gaps within the exposure can also influence the auditory effect (Finneran and Schlundt 2010, 2011, 2013; Finneran et al. 2010a,b; Popov et al. 2011, 2013a; Finneran 2012, 2015; Kastelein et al. 2012a,b; 2013b,c, 2014, 2015a; Ketten 2012).

Recent data have shown that the SEL required for TTS onset to occur increases with intermittent exposures, with some auditory recovery during silent periods between signals (Finneran et al. 2010b; Finneran and Schlundt 2011). Studies on bottlenose dolphins by Finneran et al. (2015) indicate that the potential for seismic surveys using airguns to cause auditory effects on dolphins could be lower than previously thought. Based on behavioral tests, Finneran et al. (2015) reported no measurable TTS in three bottlenose dolphins after exposure to 10 impulses from a seismic airgun with a cumulative SEL of up to ~195 dB re 1 $\mu Pa^2 \cdot s$. However, auditory evoked potential measurements were more variable; one dolphin showed a small (9 dB) threshold shift at 8 kHz (Finneran et al. 2015).

Recent studies have also shown that the SEL necessary to elicit TTS can depend substantially on frequency, with susceptibility to TTS increasing with increasing frequency above 3 kHz (Finneran and Schlundt 2010, 2011; Finneran 2012). When beluga whales were exposed to fatiguing noise with sound levels of 165 dB re 1 μPa for durations of 1–30 min at frequencies of 11.2–90 kHz, the highest TTS with the longest recovery time was produced by the lower frequencies (11.2 and 22.5 kHz); TTS effects also gradually increased with prolonged exposure time (Popov et al. 2013a). Additionally, Popov et al. (2015) demonstrated that the impacts of TTS include deterioration of signal discrimination. Kastelein et al. (2015b) reported that exposure to multiple pulses with most energy at low frequencies can lead to TTS at higher frequencies in some cetaceans, such as the harbor porpoise.

Popov et al. (2013b) reported that TTS produced by exposure to a fatiguing noise was larger during the first session (or naïve subject state) with a beluga whale than TTS that resulted from the same sound in subsequent sessions (experienced subject state). Similarly, several other studies have shown that some marine mammals (e.g., bottlenose dolphins, false killer whales) can decrease their hearing sensitivity in order to mitigate the impacts of exposure to loud sounds (e.g., Nachtigall and Supin 2013, 2014, 2015)

Previous information on TTS for odontocetes was primarily derived from studies on the bottlenose dolphin and beluga, and that for pinnipeds has mostly been obtained from California sea lions and elephant seals (see § 3.6.4.3, § 3.7.4.3, § 3.8.4.3 and Appendix E of the PEIS). Thus, it is inappropriate to assume that onset of TTS occurs at similar received levels in all cetaceans or pinnipeds (*cf.* Southall et al. 2007). Some cetaceans or pinnipeds could incur TTS at lower sound exposures than are necessary to elicit TTS in the beluga and bottlenose dolphin or California sea lion and elephant seal, respectively.

Several studies on TTS in porpoises (e.g., Lucke et al. 2009; Popov et al. 2011; Kastelein et al. 2012a, 2013b,c, 2014, 2015a) indicate that received levels that elicit onset of TTS are lower in porpoises than in other odontocetes. Kastelein et al. (2012a) exposed a harbor porpoise to octave band noise centered at 4 kHz for extended periods. A 6-dB TTS occurred with SELs of 163 dB and 172 dB for low-intensity sound and medium-intensity sound, respectively; high-intensity sound caused a 9-dB TTS at a SEL of 175 dB (Kastelein et al. 2012a). Kastelein et al. (2013b) exposed a harbor porpoise to a long, continuous 1.5-kHz tone, which induced a 14-dB TTS with a total SEL of 190 dB. Popov et al. (2011) examined the effects of fatiguing noise on the hearing threshold of Yangtze finless porpoises when exposed to frequencies of 32–128 kHz at 140–160 dB re 1 µPa for 1–30 min. They found that an exposure of higher level and shorter duration produced a higher TTS than an exposure of equal SEL but of lower level and longer duration. Popov et al. (2011) reported a TTS of 25 dB for a Yangtze finless porpoise that was exposed to high levels of 3-min pulses of half-octave band noise centered at 45 kHz with an SEL of 163 dB.

Initial evidence from exposures to non-pulses has also suggested that some pinnipeds (harbor seals in particular) incur TTS at somewhat lower received levels than do most small odontocetes exposed for similar durations (Kastak et al. 1999, 2005, 2008; Ketten et al. 2001). Kastelein et al. (2012b) exposed two harbor seals to octave-band white noise centered at 4 kHz at three mean received SPLs of 124, 136, and 148 dB re 1 µPa; TTS >2.5 dB was induced at an SEL of 170 dB (136 dB SPL for 60 min), and the maximum TTS of 10 dB occurred after a 120-min exposure to 148 dB re 1 µPa or an SEL of 187 dB. Kastelein et al. (2013c) reported that a harbor seal unintentionally exposed to the same sound source with a mean received SPL of 163 dB re 1 µPa for 1 h induced a 44 dB TTS. For a harbor seal exposed to octave-band white noise centered at 4 kHz for 60 min with mean SPLs of 124–148 re 1 µPa, the onset of PTS would require a level of at least 22 dB above the TTS onset (Kastelein et al. 2013c).

Based on the best available information at the time, Southall et al. (2007) recommended a TTS threshold for exposure to single or multiple pulses of 183 dB re 1 $\mu Pa^2 \cdot s$ for all cetaceans and 173 dB re 1 $\mu Pa^2 \cdot s$ for pinnipeds in water. For the harbor porpoise, Tougaard et al. (2015) have suggested an exposure limit for TTS as an SEL of 100–110 dB above the pure tone hearing threshold at a specific frequency; they also suggested an exposure limit of $L_{\text{eq-fast}}$ (rms average over the duration of the pulse) of 45 dB above the hearing threshold for behavioral responses (i.e., negative phonotaxis). In addition, M-weighting, as used by Southall et al. (2007), might not be appropriate for the harbor porpoise (Wensveen et al. 2014; Tougaard et al. 2015); thus, Wensveen et al. (2014) developed six auditory weighting functions for the harbor porpoise that could be useful in predicting TTS onset. Gedamke et al. (2011), based on preliminary simulation modeling that attempted to allow for various uncertainties in assumptions and variability around population means, suggested that some baleen whales whose closest point of approach to a seismic vessel is 1 km or more could experience TTS.

Hermannsen et al. (2015) reported that there is little risk of hearing damage to harbor seals or harbor porpoises when using single airguns in shallow water. Similarly, it is unlikely that a marine mammal would remain close enough to a large airgun array for sufficiently long to incur TTS, let alone PTS. There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal, even with large arrays of airguns. However, given the possibility that some mammals close to an airgun array might incur at least mild TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS (e.g., Richardson et al. 1995, p. 372*ff*; Gedamke et al. 2011). In terrestrial animals, exposure to sounds sufficiently strong to elicit a large TTS induces physiological and structural changes in the inner ear, and at some high level of sound exposure, these phenomena become non-recoverable (Le Prell 2012). At this level of sound exposure, TTS grades into PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage, but repeated or (in some cases) single exposures to a level well above that causing TTS onset might elicit PTS (e.g., Kastak and Reichmuth 2007; Kastak et al. 2008).

Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds with received levels ≥180 dB and 190 dB re 1 μPa_{rms}, respectively (NMFS 2000). These criteria have been used in establishing the EZs (or shut-down zones) planned for the proposed seismic surveys. However, those criteria were established before there was any information about minimum received levels of sounds necessary to cause auditory impairment in marine mammals.

Recommendations for science-based noise exposure criteria for marine mammals, frequency-weighting procedures, and related matters were published by Southall et al. (2007). Those recommendations were never formally adopted by NMFS for use in regulatory processes and during mitigation programs associated with seismic surveys, although some aspects of the recommendations have been taken into account in certain environmental impact statements and small-take authorizations. In July 2015, NOAA made available for a second public comment period new draft guidance for assessing the effects of anthropogenic sound on marine mammals (NOAA 2015), taking at least some of the Southall et al. recommendations into account, as well as more recent literature. At the time of preparation of this Draft EA, the content of the final guidelines and how they would be implemented are uncertain.

Nowacek et al. (2013) concluded that current scientific data indicate that seismic airguns have a low probability of directly harming marine life, except at close range. Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might, at least in theory, cause hearing impairment. Also, many marine mammals and (to a limited degree) sea turtles show some avoidance of the area where received levels of airgun sound are high enough such that hearing impairment could potentially occur. In those cases, the avoidance responses of the animals themselves would reduce or (most likely) avoid any possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) are especially susceptible to injury and/or stranding when exposed to strong transient sounds.

There is no definitive evidence that any of these effects occur even for marine mammals in close proximity to large arrays of airguns. However, Gray and Van Waerebeek (2011) have suggested a cause-effect relationship between a seismic survey off Liberia in 2009 and the erratic movement, postural instability, and akinesia in a pantropical spotted dolphin based on spatially and temporally close association with the airgun array. Additionally, a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings (e.g., Castellote and Llorens 2013).

Non-auditory effects, if they occur at all, would presumably be limited to short distances and to activities that extend over a prolonged period. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are especially unlikely to incur non-auditory physical effects. The brief duration of exposure of any given mammal, the deep water in the study area, and the planned monitoring and mitigation measures would further reduce the probability of exposure of marine mammals to sounds strong enough to induce non-auditory physical effects.

Sea Turtles

There is substantial overlap in the frequencies that sea turtles detect vs. the frequencies in airgun pulses. We are not aware of measurements of the absolute hearing thresholds of any sea turtle to waterborne sounds similar to airgun pulses. In the absence of relevant absolute threshold data, we cannot estimate how far away an airgun array might be audible. Moein et al. (1994) and Lenhardt (2002) reported TTS for loggerhead turtles exposed to many airgun pulses (see § 3.4.4 of the PEIS). This suggests that sounds from an airgun array might cause temporary hearing impairment in sea turtles if they do not avoid the (unknown) radius where TTS occurs (see Nelms et al. 2016). However, exposure duration during the proposed survey would be much less than during the aforementioned studies. Also, recent monitoring studies show that some sea turtles do show localized movement away from approaching airguns. At short distances from the source, received sound level diminishes rapidly with increasing distance. In that situation, even a small-scale avoidance response could result in a significant reduction in sound exposure.

Although it is possible that exposure to airgun sounds could cause mortality or mortal injuries in sea turtles close to the source, this has not been demonstrated and seems highly unlikely (Popper et al. 2014), especially because sea turtles appear to be highly resistant to explosives (Ketten et al. 2005 *in* Popper et al. 2014). Nonetheless, Popper et al. (2014) proposed sea turtle mortality/mortal injury criteria of 210 dB SEL or >207 dB_{peak} for sounds from seismic airguns.

The PSOs stationed on the *Langseth* would watch for sea turtles, and airgun operations would be shut down if a turtle enters the designated EZ.

4.1.1.2 Possible Effects of Other Acoustic Sources

The Kongsberg EM 122 MBES and Knudsen Chirp 3260 SBP would be operated from the source vessel during the proposed survey. Information about this equipment was provided in § 2.2.3.1 of the PEIS. A review of the expected potential effects (or lack thereof) of MBESs and SBPs, and pingers on marine mammals and sea turtles appears in § 3.4.4.3, § 3.6.4.3, § 3.7.4.3, § 3.8.4.3, and Appendix E of the PEIS.

There has been some recent attention given to the effects of MBES on marine mammals, as a result of a report issued in September 2013 by an IWC independent scientific review panel linking the operation of an MBES to a mass stranding of melon-headed whales (*Peponocephala electra*; Southall et al. 2013) off Madagascar. During May–June 2008, ~100 melon-headed whales entered and stranded in the Loza Lagoon system in northwest Madagascar at the same time that a 12-kHz MBES survey was being conducted ~65 km away off the coast. In conducting a retrospective review of available information on the event, an independent scientific review panel concluded that the Kongsberg EM 120 MBES was the most plausible behavioral trigger for the animals initially entering the lagoon system and eventually stranding. The independent scientific review panel, however, identified that an unequivocal conclusion on causality of the event was not possible because of the lack of information about the event and a number of potentially contributing factors. Additionally, the independent review panel report indicated that this incident was likely the result of a complicated confluence of environmental, social, and other factors that have a very low probability of occurring again in the future, but recommended that the potential be considered in environmental planning. It should be noted that this event is the first known marine mammal mass stranding closely associated with the operation of an MBES. Leading scientific experts knowledgeable about MBES have expressed concerns about the independent scientific review panel analyses and findings (Bernstein 2013).

Lurton (2015) modeled MBES radiation characteristics (pulse design, source level, and radiation directivity pattern) applied to a low-frequency (12-kHz), 240-dB source-level system like that used on the *Langseth*. Using Southall et al. (2007) thresholds, he found that injury impacts were possible only at very short distances, e.g., at 5 m for maximum SPL and 12 m for cumulative SEL for cetaceans; corresponding distances for behavioural response were 9 m and 70 m. For pinnipeds, "all ranges are multiplied by a factor of 4" (Lurton 2015:209).

There is no available information on marine mammal behavioral response to MBES sounds (Southall et al. 2013) or sea turtle responses to MBES systems. Much of the literature on marine mammal response to sonars relates to the types of sonars used in naval operations, including Low-Frequency Active (LFA) sonars (e.g., Miller et al. 2012; Sivle et al. 2012) and Mid-Frequency Active (MFA) sonars (e.g., Tyack et al. 2011; Melcón et al. 2012; Miller et al. 2012; DeRuiter et al. 2013a,b; Goldbogen et al. 2013; Baird et al. 2014; Wensveen et al. 2015). However, the MBES sounds are quite different from naval sonars. Ping duration of the MBES is very short relative to naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the MBES for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth; naval sonars often use near-horizontally-directed sound. In addition, naval sonars have higher duty cycles. These factors would all reduce the sound energy received from the MBES relative to that from naval sonars.

In the fall of 2006, an Ocean Acoustic Waveguide Remote Sensing (OAWRS) experiment was carried out in the Gulf of Maine (Gong et al. 2014); the OAWRS emitted three frequency-modulated (FM) pulses centered at frequencies of 415, 734, and 949 Hz (Risch et al. 2012). Risch et al. (2012) found a reduction in humpback whale song in the Stellwagen Bank National Marine Sanctuary during OAWRS activities that were carried out ~200 km away; received levels in the sanctuary were 88–110 dB re 1 µPa. In contrast, Gong et al. (2014) reported no effect of the OAWRS signals on humpback whale vocalizations in the Gulf of Maine. Range to the source, ambient noise, and/or behavioral state may have differentially influenced the behavioral responses of humpbacks in the two areas (Risch et al. 2014).

Deng et al. (2014) measured the spectral properties of pulses transmitted by three 200-kHz echosounders and found that they generated weaker sounds at frequencies below the center frequency (90–130 kHz). These sounds are within the hearing range of some marine mammals, and the authors suggested that they could be strong enough to elicit behavioral responses within close proximity to the sources, although they would be well below potentially harmful levels. Hastie et al. (2014) reported behavioral responses by grey seals to echosounders with frequencies of 200 and 375 kHz.

Despite the aforementioned information that has recently become available, this Draft EA is in agreement with the assessment presented in § 3.4.7, 3.6.7, 3.7.7, and 3.8.7 of the PEIS that operation of MBESs, SBPs, and pingers is not likely to impact marine mammals and is not expected to affect sea turtles, (1) given the lower acoustic exposures relative to airguns and (2) because the intermittent and/or narrow downward-directed nature of these sounds would result in no more than one or two brief ping exposures of any individual marine mammal or sea turtle given the movement and speed of the vessel. Also, for sea turtles, the associated frequency ranges are above their known hearing range.

4.1.1.3 Other Possible Effects of Seismic Surveys

Other possible effects of seismic surveys on marine mammals and/or sea turtles include masking by vessel noise, disturbance by vessel presence or noise, and injury or mortality from collisions with vessels or entanglement in seismic gear.

Vessel noise from the *Langseth* could affect marine animals in the proposed survey areas. Sounds produced by large vessels generally dominate ambient noise at frequencies from 20 to 300 Hz (Richardson et al. 1995). However, some energy is also produced at higher frequencies (Hermannsen et al. 2014); low levels of high-frequency sound from vessels has been shown to elicit responses in harbor porpoise (Dyndo et al. 2015). Ship noise, through masking, can reduce the effective communication distance of a marine mammal if the frequency of the sound source is close to that used by the animal, and if the sound is present for a significant fraction of time (e.g., Richardson et al. 1995; Clark et al. 2009; Jensen et al. 2009; Gervaise et al. 2012; Hatch et al. 2012; Rice et al. 2014). In addition to the frequency and duration of the masking sound, the strength, temporal pattern, and location of the introduced sound also play a role in the extent of the masking (Branstetter et al. 2013; Finneran and Branstetter 2013). Branstetter et al. (2013) reported that time-domain metrics are also important in describing and predicting masking. In order to compensate for increased ambient noise, some cetaceans are known to increase the source levels of their calls in the presence of elevated noise levels from shipping, shift their peak frequencies, or otherwise change their vocal behavior (e.g., Parks et al. 2011, 2012; Castellote et al. 2012; Melcón et al. 2012; Tyack and Janik 2013; Luís et al. 2014; Sairanen 2014; Papale et al. 2015). Holt et al. (2015) reported that changes in vocal modifications can have increased energetic costs for individual marine mammals.

Baleen whales are thought to be more sensitive to sound at these low frequencies than are toothed whales (e.g., MacGillivray et al. 2014), possibly causing localized avoidance of the proposed survey areas during seismic operations. Reactions of gray and humpback whales to vessels have been studied, and there is limited information available about the reactions of right whales and rorquals (fin, blue, and minke whales). Reactions of humpback whales to boats are variable, ranging from approach to avoidance (Payne 1978; Salden 1993). Baker et al. (1982, 1983) and Baker and Herman (1989) found humpbacks often move away when vessels are within several kilometers. Humpbacks seem less likely to react overtly when actively feeding than when resting or engaged in other activities (Krieger and Wing 1984, 1986).

Many odontocetes show considerable tolerance of vessel traffic, although they sometimes react at long distances if confined by ice or shallow water, if previously harassed by vessels, or have had little or no recent exposure to ships (Richardson et al. 1995). Dolphins of many species tolerate and sometimes approach vessels. Some dolphin species approach moving vessels to ride the bow or stern waves (Williams et al. 1992). Pirotta et al. (2015) noted that the physical presence of vessels, not just ship noise, disturbed the foraging activity of bottlenose dolphins. There are few data on the behavioral reactions of beaked whales to vessel noise, though they seem to avoid approaching vessels (e.g., Würsig et al. 1998) or dive for an extended period when approached by a vessel (e.g., Kasuya 1986). Based on a single observation, Aguilar Soto et al. (2006) suggest foraging efficiency of Cuvier's beaked whales may be reduced by close approach of vessels.

The PEIS concluded that project vessel sounds would not be at levels expected to cause anything more than possible localized and temporary behavioral changes in marine mammals or sea turtles, and would not be expected to result in significant negative effects on individuals or at the population level. In addition, in all oceans of the world, large vessel traffic is currently so prevalent that it is commonly considered a usual source of ambient sound.

Another concern with vessel traffic is the potential for striking marine mammals or sea turtles. Information on vessel strikes is reviewed in § 3.4.4.4, § 3.6.4.4, and § 3.8.4.4 of the PEIS. The PEIS concluded that the risk of collision of seismic vessels or towed/deployed equipment with marine mammals or sea turtles exists but is extremely unlikely, because of the relatively slow operating speed (typically 7–9 km/h) of the vessel during seismic operations, and the generally straight-line movement of the seismic vessel. There has been no history of marine mammal vessel strikes with the R/V *Langseth*, or its predecessor, R/V *Maurice Ewing* over the last two decades.

Entanglement of sea turtles in seismic gear is also a concern (Nelms et al. 2016). There have been reports of turtles being trapped and killed between the gaps in tail-buoys offshore from West Africa (Weir 2007); however, these tailbuoys are significantly different then those used on the *Langseth*. In April 2011, a dead olive ridley turtle was found in a deflector foil of the seismic gear on the *Langseth* during equipment recovery at the conclusion of a survey off Costa Rica, where sea turtles were numerous. Such incidents are possible, but that was the only case of sea turtle entanglement in seismic gear for the *Langseth*, which has been conducting seismic surveys since 2008, or for its predecessor, R/V *Maurice Ewing*, during 2003–2007. Towing the seismic equipment during the proposed survey is not expected to significantly interfere with sea turtle movements, including migration.

4.1.1.4 Mitigation Measures

Several mitigation measures are built into the proposed seismic surveys as an integral part of the planned activity. These measures include the following: ramp ups; typically two, however a minimum of one dedicated observer maintaining a visual watch during all daytime airgun operations; two observers for 30 min before and during ramp ups; PAM during the day and night to complement visual monitoring (unless the system and back-up systems are damaged during operations); and power downs (or if necessary shut downs) when mammals or turtles are detected in or about to enter designated EZ. These mitigation measures are described in § 2.4.4.1 of the PEIS and summarized earlier in this document, in § II (2.1.3). The fact that the 36-airgun array, because of its design, would direct the majority of the energy downward, and less energy laterally, is also an inherent mitigation measure.

Previous and subsequent analysis of the potential impacts takes account of these planned mitigation measures. It would not be meaningful to analyze the effects of the planned activity without mitigation, as the mitigation (and associated monitoring) measures are a basic part of the activity, and would be implemented under the Proposed Action.

4.1.1.5 Potential Numbers of Cetaceans Exposed to Received Sound Levels ≥160 dB

All anticipated takes would be "takes by harassment" as described in § I, involving temporary changes in behavior. The mitigation measures to be applied would minimize the possibility of injurious takes. (However, as noted earlier and in the PEIS, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below, we describe methods to estimate the number of potential exposures to sound levels ≥160 dB re 1 μPa_{rms} and present estimates of the numbers of marine mammals that could be affected during the proposed seismic survey. The estimates are based on consideration of the number of marine mammals that could be disturbed appreciably by the seismic surveys off the coast of Chile in non-Territorial Waters. The main sources of distributional and numerical data used in deriving the estimates are described in the next subsection.

***Basis for Estimating Exposure*.—**The estimates are based on a consideration of the number of marine mammals that could be within the area around the operating airgun array where received levels of sound ≥160 dB re 1 µPa$_{rms}$ are predicted to occur (see Table 1). The estimated numbers are based on the densities (numbers per unit area) of marine mammals expected to occur in the area in the absence of a seismic survey. To the extent that marine mammals tend to move away from seismic sources before the sound level reaches the criterion level and tend not to approach an operating airgun array, these estimates likely overestimate the numbers actually exposed to the specified level of sound. The overestimation is expected to be particularly large when dealing with the higher sound level criteria, e.g., 180 dB re 1 µPa$_{rms}$, as animals are more likely to move away when received levels are higher. Likewise, they are less likely to approach within the ≥180 or 190 dB re 1 µPa$_{rms}$ radii than they are to approach within the considerably larger ≥160 dB radius.

To our knowledge, no systematic aircraft- or ship-based surveys have been conducted for marine mammals in waters of the southeast Pacific Ocean off the coast of Chile. Similar to methodology used for the 2012 survey off Chile by SIO, for most cetacean species, we used densities from extensive NMFS SWFSC cruises (Ferguson and Barlow 2001, 2003; Barlow 2003, 2010; Forney 2007) in one province of Longhurst's (2006) pelagic biogeography, the California Current Province (CALC). That province is similar to the Humboldt Current Coastal Province (HUMB) in which the proposed surveys are located; both are eastern boundary currents in this Pacific Coastal Biome that feature narrow continental shelves, upwelling, high productivity, and fluctuating fishery resources (sardines and anchovies). Specifically, we used the 1986–1996 summer/fall data from Ferguson and Barlow's (2001, 2003) 5º×5º blocks whose latitudes and distances from shore are analogous to those of the proposed survey areas (71, 72, 85, 86, 102, and 103 for the northern proposed survey; 58, 59, 71, 72, 85, and 86 for the central proposed survey; and 34, 35, 36, 46, 47, 48, 58, and 59 for the southern proposed survey), and the 2001 data from Barlow's (2003) California (CA) stratum and the 2005 and 2008 data, respectively, from Forney's (2007) and Barlow's (2010) southern CA strata for all three proposed survey areas. The densities used were survey effort-weighted means for the locations (blocks or States). The 2001, 2005, and 2008 surveys off CA were conducted up to ~556 km offshore in areas that overlap with the blocks selected from Ferguson and Barlow (2001, 2003).

Densities used here were either taken directly from the reports (Ferguson and Barlow 2001, 2003; Barlow 2003; Forney 2007), or were calculated using standard line-transect methods (Buckland et al. 2001) from sightings, mean group size, and survey effort data from the report (Barlow 2010). The survey efforts used to weight mean densities from the surveys were from the survey reports except for the 2005 data for southern CA, where the survey effort was estimated based on measurements of tracklines in Figure 1 of Forney (2007). All reported densities have been corrected for both detectability and availability bias by the authors or for the calculated densities from Barlow (2010), using data therein. Detectability bias [$f(0)$] is associated with diminishing sightability with increasing lateral distance from the trackline; availability bias [$g(0)$] refers to the fact that there is <100% probability of sighting an animal that is present along the survey trackline. Densities reported for unidentified sightings (e.g., *Kogia* sp., rorquals, large whales) were allocated to appropriate species in proportion to the calculated densities of those species in the areas selected. Calculated densities are shown in Tables 4–6.

Using the aforementioned methods yielded density estimates of 0.54, 2.10, and 2.07/km^2 for blue whales in the northern, central, and southern proposed survey areas, respectively. Since a feeding aggregation area for this species occurs between 39°S and 44°S during February–April, we used data from surveys off southern Chile (up to 40 km from shore) by Galletti Vernazzani et al. (2012) to estimate density for the southern proposed survey area for austral summer/fall. Density was calculated using standard line-transect methods (Buckland et al. 2001) from sightings, mean group size, and survey effort data for sub-areas A-D collected during aerial surveys conducted off southern Chile between 2004 and

TABLE 4. Densities and estimates of the possible numbers of individuals that could be exposed to ≥160 and 180 or 190 dB re 1 µPa$_{rms}$ during the northern proposed seismic survey off Chile in the south-east Pacific Ocean in 2016/2017. The proposed sound source consists of a 36-airgun array with a total discharge volume of ~6600 in^3. Species in italics are listed under the ESA as endangered. The column of numbers in boldface shows the numbers of Level A and B "takes" for which authorization is requested.

Species	Estimated Density[1] (#/1000 km^2)	Calculated Take, NMFS Daily Method[2] Level A[3]	Level B[4]	Requested Take as % of Pop.[5]	Requested Level A + B Take Authorization[6]
Mysticetes					
Southern right whale	*0*	*0*	0	*0.10*	***12[7]***
Humpback whale	*0.32*	*4*	23	*0.10*	***42[7]***
Common (dwarf) minke whale	0.34	4	25	0.01	**29**
Antarctic minke whale	0	0	0	<0.01	**2[8]**
Bryde's whale	0.47	6	34	0.38	**40**
Sei whale	*0*	*0*	0	*0.10*	***10[7]***
Fin whale	*1.40*	*19*	100	*0.79*	***119***
Blue whale	*0.54*	*7*	38	*1.20*	***45***
Odontocetes					
Sperm whale	*1.19*	*16*	85	*2.44*	***101***
Dwarf sperm whale	8.92	118	639	6.76	**757**
Pygmy sperm whale	2.73	36	196	N.A.	**232**
Cuvier's beaked whale	2.36	31	169	1.00	**200**
Pygmy beaked whale	0.70	9	50	0.23	**59**
Mesoplodont spp.[9]	1.95	26	139	0.65	**165**
Rough-toothed dolphin	7.05	94	505	0.56	**599**
Common bottlenose dolphin	18.4	245	1321	0.47	**1566**
Striped dolphin	61.4	815	4395	0.54	**5210**
Short-beaked common dolphin	356.3	4731	25,522	1.71	**30,253**
Long-beaked common dolphin	50.3	667	3600	N.A.	**4267**
Dusky dolphin	13.7	182	985	N.A.	**1167**
Southern right whale dolphin	3.34	44	239	N.A.	**283**
Risso's dolphin	29.8	396	2137	2.29	**2533**
Pygmy killer whale	1.31	17	95	0.29	**112**
False killer whale	0.63	8	45	0.13	**53**
Killer whale	0.23	3	17	0.23	**20**
Short-finned pilot whale	0	0	0	0.01	**18[8]**
Long-finned pilot whale	1.09	14	78	0.02	**92**
Burmeister's porpoise	5.15	68	369	N.A.	**437**
Pinnipeds					
Juan Fernandez fur seal	0	0	0	0.01	**3[8]**
South American fur seal	37.9	156	3061	13.08	**3217**
South American sea lion	393.0	1621	31,750	13.08	**33,371**

[1] No correction factors were applied to these calculations; see text for density sources.
[2] Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area on one selected day (see text) multiplied by the number of survey days (28) times 1.25; daily ensonified areas used to calculate Level B takes = full 160-dB (2426.1 km^2) area minus the 180-dB (379.4 km^2) or 190-dB (117.8 km^2) areas.
[3] Level A takes if there were no mitigation measures, based on the 180- and 190-dB criteria for cetaceans and pinnipeds, respectively.
[4] Level B takes, based on the 160-dB criterion, excluding exposures to sound levels ≥180 dB (Level A takes).
[5] Requested Level A and B takes (used by NMFS as proxy for number of individuals exposed) expressed as % of population; N.A. = population size not available (see Table 3).
[6] Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated.
[7] Requested take authorization increased to 0.1% for ESA-listed species; increases made to Level B takes only.
[8] Requested take authorization (Level B onlyl) increased to mean group size for non-listed species (see text for sources).
[9] May include Gray's and/or Blainville's beaked whales.

TABLE 5. Densities and estimates of the possible numbers of individuals that could be exposed to ≥160 and 180 or 190 dB re 1 μPa$_{rms}$ during the central proposed seismic survey off Chile in the southeast Pacific Ocean during 2016/2017. The proposed sound source consists of a 36-airgun array with a total discharge volume of ~6600 in^3. Species in italics are listed under the ESA as endangered. The column of numbers in boldface shows the numbers of Level A and B "takes" for which authorization is requested.

Species	Estimated Density[1] (#/1000 km^2)	Calculated Take, NMFS Daily Method[2] Level A[3]	Level B[4]	Requested Take as % of Pop.[5]	Requested Level A + B Take Authorization[6]
Mysticetes					
Southern right whale	*0*	*0*	0	*0.10*	***12[7]***
Pygmy right whale	0	0	0	N.A.	**1[8]**
Humpback whale	*0.43*	*1*	4	*0.10*	***42[7]***
Common (dwarf) minke whale	0.34	1	3	<0.01	**4**
Antarctic minke whale	0	0	0	<0.01	**2[8]**
Bryde's whale	0.41	1	4	0.05	**5**
Sei whale	*0*	*0*	0	*0.10*	***10[7]***
Fin whale	*1.96*	*4*	20	*0.16*	***24***
Blue whale	*2.10*	*4*	22	*0.67*	***26***
Odontocetes					
Sperm whale	*1.22*	*2*	13	*0.36*	***15***
Dwarf sperm whale	7.98	15	82	0.87	**97**
Pygmy sperm whale	2.98	6	30	N.A.	**36**
Cuvier's beaked whale	3.02	6	31	0.18	**37**
Shepherd's beaked whale	0	0	0	N.A.	**10[8]**
Southern bottlenose whale	0	0	0	0.01	**4[8]**
Pygmy beaked whale	0.55	1	6	0.03	**7**
Mesoplodont spp.[9]	1.54	3	16	0.07	**19**
Chilean dolphin	21.2	40	219	N.A.	**259**
Common bottlenose dolphin	12.3	23	128	0.04	**151**
Striped dolphin	46.7	87	483	0.06	**570**
Short-beaked common dolphin	503.5	942	5207	0.35	**6149**
Dusky dolphin	14.8	28	153	N.A.	**181**
Peale's dolphin	21.2	40	219	N.A.	**259**
Hourglass dolphin	0	0	0	<0.01	**5[8]**
Southern right whale dolphin	6.07	11	63	N.A.	**74**
Risso's dolphin	21.2	40	219	0.23	**259**
Pygmy killer whale	0	0	0	0.07	**28[8]**
False killer whale	0.54	1	6	0.03	**11[8]**
Killer whale	0.28	1	2	0.06	**5[8]**
Short-finned pilot whale	0	0	0	0.01	**18[8]**
Long-finned pilot whale	0.94	2	9	<0.01	**18[8]**
Burmeister's porpoise	4.92	9	51	N.A.	**60**
Pinnipeds					
Juan Fernandez fur seal	0	0	0	0.01	**3[8]**
South American fur seal	37.9	22	441	1.88	**463**
South American sea lion	393.0	225	4575	1.88	**4800**
Southern elephant seal	0	0	0	<0.01	**2[8]**

[1] No correction factors were applied to these calculations; see text for density sources. N.A. = not available.
[2] Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area on one selected day (see text) multiplied by the number of survey days (5) times 1.25; daily ensonified areas used to calculate Level B takes = full 160-dB (1954.0 km^2) area minus the 180-dB (299.3 km^2) or 190-dB (91.8 km^2) areas.
[3] Level A takes if there were no mitigation measures, based on the 180- and 190-dB criteria for cetaceans and pinnipeds, respectively.
[4] Level B takes, based on the 160-dB criterion, excluding exposures to sound levels ≥180 dB (Level A takes).
[5] Requested Level A and B takes (used by NMFS as proxy for number of individuals exposed) expressed as % of population.
[6] Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated.
[7] Requested take authorization increased to 0.1% for ESA-listed species; increases made to Level B takes only.
[8] Requested take authorization (Level B only) increased to mean group size for non-listed species (see text for sources).
[9] May include Hector's, Gray's, Andrew's, Blainville's, strap-toothed, and/or spade-toothed beaked whales.

TABLE 6. Densities and estimates of the possible numbers of individuals that could be exposed to ≥160 and 180 or 190 dB re 1 μPa$_{rms}$ during the southern proposed seismic survey off Chile in the south-east Pacific Ocean in 2016/2017. The proposed sound source consists of a 36-airgun array with a total discharge volume of ~6600 in^3. Species in italics are listed under the ESA as endangered. The column of numbers in boldface shows the numbers of Level A and B "takes" for which authorization is requested.

Species	Estimated Density[1] (#/1000 km^2)	Calculated Take, NMFS Daily Method[2] Level A[3]	Level B[4]	Requested Take as % of Pop.[5]	Requested Level A + B Take Authorization[6]
Mysticetes					
Southern right whale	*0*	*0*	0	*0.10*	***12[7]***
Pygmy right whale	0	0	0	N.A.	**1[8]**
Humpback whale	*1.22*	*14*	85	*0.24*	***99***
Common (dwarf) minke whale	0.61	7	42	0.01	**49**
Antarctic minke whale	0	0	0	<0.01	**2[8]**
Bryde's whale	0.03	0	3	0.03	**3**
Sei whale	*0.02*	*0*	2	*0.10*	***10[7]***
Fin whale	*2.43*	*28*	168	*1.31*	***196***
Blue whale	*4.78[9]*	*55*	332	*10.2*	***387***
Odontocetes					
Sperm whale	*1.32*	*15*	92	*2.58*	***107***
Dwarf sperm whale	0	0	0	0.02	**2[8]**
Pygmy sperm whale	4.14	47	288	N.A.	**335**
Cuvier's beaked whale	4.02	46	280	1.63	**326**
Shepherd's beaked whale	0	0	0	N.A.	**10[8]**
Southern bottlenose whale	0	0	0	0.01	**4[8]**
Pygmy beaked whale	0	0	0	0.01	**3[8]**
Blainville's beaked whale	0.31	4	21	0.10	**25**
Mesoplodont spp.[10]	0.31	4	21	N.A.	**25**
Chilean dolphin	10.9	125	758	N.A.	**883**
Common bottlenose dolphin	2.72	31	190	0.07	**221**
Striped dolphin	17.7	202	1231	0.15	**1433**
Short-beaked common dolphin	516.9	5903	35,956	2.37	**41,859**
Dusky dolphin	29.9	341	2079	N.A.	**2420**
Peale's dolphin	10.9	125	758	N.A.	**883**
Hourglass dolphin	0	0	0	<0.01	**5[8]**
Southern right whale dolphin	9.79	112	681	N.A.	**793**
Risso's dolphin	10.9	125	758	0.80	**883**
Pygmy killer whale	0	0	0	0.07	**28[8]**
False killer whale	0	0	0	0.03	**11[8]**
Killer whale	0.73	8	51	0.70	**59**
Long-finned pilot whale	0.53	6	37	0.02	**43**
Short-finned pilot whale	0	0	0	<0.01	**18[7]**
Burmeister's porpoise	55.4	632	3853	N.A.	**4485**
Pinnipeds					
Juan Fernandez fur seal	0	0	0	0.01	**3[8]**
South American fur seal	37.9	131	2937	12.5	**3068**
South American sea lion	393.0	1360	30,464	12.5	**31,824**
Southern elephant seal	0	0	0	<0.01	**2[8]**

[1] Except for blue whales, no correction factors were applied to these calculations; see text for density sources; N.A. = not available.
[2] Take using NMFS daily method for calculating ensonified area: estimated density multiplied by the daily ensonified area on 3 selected days, 1 in each of 3 subareas, multiplied by the number of survey days (9) in each subarea times 1.25; daily ensonified areas used to calculate Level B takes = full 160-dB (7197.9 km^2) area minus the 180-dB (1015.0 km^2) or 190-dB (307.6 km^2) areas.
[3] Level A takes if there were no mitigation measures, based on the 180- and 190-dB criteria for cetaceans and pinnipeds, respectively.
[4] Level B takes, based on the 160-dB criterion, excluding exposures to sound levels ≥180 dB (Level A takes).
[5] Requested Level A and B takes (used by NMFS as proxy for number of individuals exposed) expressed as % of population.
[6] Requested take authorization is Level A plus Level B calculated takes, unless otherwise indicated.
[7] Requested take authorization increased to 0.1% for ESA-listed species; increases made to Level B takes only.
[8] Requested take authorization (Level B) increased to mean group size for non-listed species (see text for sources).
[9] Density of 9.56/km^2 based on Galletti et al. (2012), reduced by 50%; a lower density (2.07/km^2) is expected during winter/spring.
[10] May include Hector's, Gray's, Andrew's, Blainville's, strap-toothed, and/or spade-toothed beaked whales.

2010 (Galletti Vernazzani et al. 2012). The density was corrected for both detectability and availability bias using data from Barlow (2010). Given that aggregations of blue whales are expected to occur only in half of the southern proposed survey area (south of 39°S), and that the proposed survey area extends farther offshore (>100 km) than surveys by Galletti Vernazzani et al. (2012), we corrected the calculated density (9.56/km^2) by reducing it by 50%, which resulted in an estimate of 4.78/km^2 for austral summer/fall (Table 6). The density for austral winter/spring is expected to be lower (~2.07/km^2).

We have used densities for some Northern Hemisphere species that are similar to Southern Hemisphere species that occur in the proposed survey areas: we used northern right whale dolphin for southern right whale dolphin, Pacific white-sided dolphin for dusky dolphin (both are *Lagenorhynchus* species, occupy shelf waters, usually have group sizes 10–100, and feed primarily on small, schooling fish), and Dall's porpoise for Burmeister's porpoise (both are *Phocoena* species, primarily coastal, usually alone or in small groups, and feed primarily on small, schooling fish). Densities for short-finned pilot whales were used for long-finned pilot whales, as the latter are much more abundant off Chile (see § 3.3.2.26). In the case of Peale's and Chilean dolphins, we used the same density as for Risso's dolphin, because all three delphinid species are predicted to be uncommon in the central and southern proposed survey areas (see Table 3).

The at-sea density estimate for South American sea lions was calculated during an ~1800-km repeated trackline survey off the Chilean northern Patagonia coast (41.5–45.5°S) by Bedriñana-Romano et al. (2014). The densities have been corrected for detectability bias by the authors and assumed an availability bias of 1. The at-sea density estimate for South American fur seals for northern and southern Chile was also based on the South American sea lion density reported by Bedriñana-Romano et al. (2014); it was estimated to be a fraction of the South American sea lion density using the proportional difference in population sizes for each species (see Table 3). No density estimates are available for the Juan Fernandez fur seal or southern elephant seal, both of which are considered rare. Their density estimates were thus considered to be zero.

There is some uncertainty about the representativeness of the estimated density data and the assumptions used in their calculations. Oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the ETP, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species. Thus, for some species, the densities derived from past surveys may not be representative of the densities that would be encountered during the proposed seismic surveys. However, the approach used here is based on the best available data. The calculated exposures that are based on these densities are best estimates for the proposed survey for any time of the year.

The estimated numbers of individuals potentially exposed are based on the 160-dB re 1 μPa_{rms} criterion for all cetaceans and pinnipeds. It is assumed that marine mammals exposed to airgun sounds that strong could change their behavior sufficiently to be considered "taken by harassment". Tables 4–6 show the density estimates calculated as described above and the estimates of the number of marine mammals that potentially could be exposed to ≥160 dB re 1 μPa_{rms} during the seismic surveys in the northern, central, and southern proposed survey areas off Chile outside of Territorial Waters, respectively, if no animals moved away from the survey vessel. The *Requested Take Authorization* is given in the far right column of Tables 4–6. For all species, including those for which densities were not available or zero, we have included a *Requested Take Authorization* for the mean group size for the non-listed species where that number was higher than the calculated take, and for at least 0.1% of the population for ESA-listed species. The species and sources used include the pygmy right whale (Kemper 2009); Antarctic minke whale and hourglass dolphin (Williams et al. 2006); Shepherd's beaked whale (Mead 2009); southern bottlenose whale (Gowans 2009); dwarf sperm, pygmy killer, false killer, killer, and pilot whales, and *Mesoplodon* sp. for pygmy beaked whale (Wade and Gerrodette 1993); and southern elephant seal (Branch and Butterworth 2001). The mean group size for the South American fur seal (Dassis et al. 2012) was used for the Juan Fernandez fur seal. Although marine otters could be exposed to sounds ≥160 dB in the nearshore environment, no takes are requested, as all otters would occur within Territorial Waters of Chile where the MMPA does not apply.

It should be noted that the following estimates of exposures assume that the proposed surveys would be completed; in fact, the calculated takes ***have been increased by 25%*** (see below). Thus, the following estimates of the numbers of marine mammals potentially exposed to sounds ≥160 dB re 1 μPa_{rms} are precautionary and probably overestimate the actual numbers of marine mammals that could be involved.

Consideration should be given to the hypothesis that delphinids are less responsive to airgun sounds than are mysticetes, as referenced in both the PEIS and §4.1.1.1 of this document. The 160-dB (rms) criterion currently applied by NMFS, on which the Level B estimates are based, was developed primarily using data from gray and bowhead whales. The estimates of "takes by harassment" of delphinids are thus considered precautionary. As noted previously, in July 2015, NOAA made available for public comment revised draft guidance for assessing the effects of anthropogenic sound on marine mammals (NOAA 2015), although at the time of preparation of this Draft EA, the content of the final guidelines and how they would be implemented are uncertain. Available data suggest that the current use of a 160-dB criterion could be improved upon, as behavioral response might not occur for some percentage of marine mammals exposed to received levels >160 dB, whereas other individuals or groups might respond in a manner considered as "taken" to sound levels <160 dB (NMFS 2013c). It has become evident that the context of an exposure of a marine mammal to sound can affect the animal's initial response to the sound (NMFS 2013c).

Potential Number of Marine Mammals Exposed to ≥160 dB.—The number of marine mammals that could be exposed to airgun sounds with received levels ≥160 and ≥180 or ≥190 dB re 1 μPa_{rms} on one or more occasions have been estimated using a method required by NMFS for calculating the marine area that would be within the 160-dB, 180-dB, and 190-dB radii around the operating seismic source, along with the expected density of animals in the area. NMFS' method was developed to account in some way for the number of exposures as well as the number of individuals exposed. It involves selecting a seismic trackline(s) that could be surveyed on one day; the 160-km line(s) selected had a proportion of depth intervals (>100 m, 100–1000 m, and >1000 m) with their associated radii that was roughly similar to that of the entire survey. The area expected to be ensonified on that day was determined by entering the planned survey lines into a MapInfo GIS, using the GIS to identify the relevant areas by "drawing" the applicable 160-dB, 180-dB, or 190-dB buffer (see Table 1) around each seismic line, and then calculating the total area within the buffers that was outside Territorial Waters. For the southern proposed survey area, it was decided to select daily lines in three subareas because of the geometry of the tracklines and depth contours: the inner north-south line, the outer north-south line, and one east-west line. The ensonified areas were then multiplied by the number of survey days increased by 25%; this is equivalent to adding an additional 25% to the proposed line km for a total of ~12,040 km.

Applying the approach described above, the resulting ensonified areas were ~84,913 km^2, 12,213 km^2, and 80,976 km^2 for the 160-dB isopleth during the northern, central, and southern proposed surveys, respectively. The approach assumes that no cetaceans would move away or toward the trackline in response to increasing sound levels before the levels reach 160 dB as the *Langseth* approaches.

The estimates of the numbers of cetaceans and pinnipeds that could be exposed to seismic sounds with received levels ≥180 dB re 1 μPa_{rms} or 190 dB re 1 μPa_{rms}, respectively, if there were no mitigation measures (power downs or shut downs when PSOs observed animals approaching or inside the EZs) are also given in Tables 4–6. It is emphasized that those numbers considerably overestimate actual Level A takes because mitigation measures would strongly reduce if not eliminate any such takes.

Northern Proposed Survey Area

The estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} in the northern proposed survey area is 48,366 (Table 4). That total includes 292 cetaceans listed as ***Endangered*** under the ESA: 119 fin whales, 101 sperm whales, 45 blue whales, and 27 humpback whales, representing 0.79%, 2.44%, 1.20%, and 0.07% of their regional populations, respectively.

In addition, 424 beaked whales could be exposed. Most (95.4%) of the cetaceans potentially exposed would be delphinids; the short-beaked common dolphin, striped dolphin, long-beaked common dolphin, and Risso's dolphin are estimated to be the most common delphinid species in the area, with estimates of 30,253, 5210, 4267, and 2533 exposed to ≥160 dB re 1 μPa_{rms}, respectively (0.54–2.29% of the regional populations). The estimate of the number of pinnipeds that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} is 36,588, most (91.2%) of which would be South American sea lions (13.1% of the regional population).

Central Proposed Survey Area

The estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} in the central proposed survey area is 8258 (Table 5). That total includes 70 cetaceans listed as ***Endangered*** under the ESA: 26 blue whales, 24 fin whales, 15 sperm whales, and 5 humpback whales, representing 0.67%, 0.16%, 0.36%, and 0.01% of their regional populations, respectively.

In addition, 63 beaked whales could be exposed. Most (95.9%) of the cetaceans potentially exposed would be delphinids; the short-beaked common dolphin and the striped dolphin are estimated to be the most common delphinid species in the area, with estimates of 6149 and 570 exposed to ≥160 dB re 1 μPa_{rms}, respectively (0.35% and 0.06% of their regional populations, respectively). The estimate of the number of pinnipeds that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} is 5263, most (91.2%) of which would be South American sea lions (1.9% of the regional population).

Southern Proposed Survey Area

The estimate of the number of cetaceans that could be exposed to seismic sounds with received levels ≥160 dB re 1 μPa_{rms} in the southern proposed survey area is 55,516 (Table 6). That total includes 791 cetaceans listed as ***Endangered*** under the ESA: 387 blue whales, 196 fin whales, 107 sperm whales, 99 humpback whales, and 2 sei whales, representing 10.2%, 1.31%, 2.58%, 0.24%, and 0.02% of their regional populations, respectively.

In addition, 376 beaked whales could be exposed. Most (89.1%) of the cetaceans potentially exposed would be delphinids; the short-beaked common dolphin, Burmeister's porpoise, dusky dolphin, and striped dolphin are estimated to be the most common delphinid species in the area, with estimates of

41,859, 4485, 2420, and 1433 exposed to ≥160 dB re 1 µPa$_{rms}$, respectively (0.15–2.37% of the regional populations). The estimate of the number of individual pinnipeds that could be exposed to seismic sounds with received levels ≥160 dB re 1 µPa$_{rms}$ is 34,892, most (91.2%) of which would be South American sea lions (12.5% of the regional population).

4.1.1.6 Conclusions for Marine Mammals and Sea Turtles

The proposed seismic project would involve towing a 36-airgun array with a total discharge volume of 6600 in^3 that introduces pulsed sounds into the ocean. Routine vessel operations, other than the proposed seismic operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking".

Marine Mammals.—In § 3.6.7, § 3.7.7, and § 3.8.7, the PEIS concluded that airgun operations with implementation of the proposed monitoring and mitigation measures could result in a small number of Level B behavioral effects in some mysticete, odontocete, and pinniped species and that Level A effects were highly unlikely. NSF, L-DEO, OSU and UT were required by NMFS to calculate and request potential Level A takes for the Proposed Action (following a different methodology than used in the PEIS and most previous analyses for NSF-funded seismic surveys). For two past NSF-funded seismic surveys, NMFS issued small numbers of Level A take for some marine mammal species for the remote possibility of low-level physiological effects; however, NMFS expected neither mortality nor serious injury of marine mammals to result from the surveys (NMFS 2015e, 2016).

In this analysis, estimates of the numbers of marine mammals that could be exposed to airgun sounds during the proposed program have been presented, together with the requested "take authorization". The estimated numbers of animals potentially exposed to sound levels sufficient to cause Level A and/or B harassment are low percentages of the regional population sizes (Tables 4–6). The estimates are likely overestimates of the actual number of animals that would be exposed to and would react to the seismic sounds. The reasons for that conclusion are outlined above. The relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations. Therefore, no significant impacts on cetaceans or pinnipeds would be expected from the proposed activity.

In decades of seismic surveys carried out by the *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related marine mammal injuries or mortality. Also, actual numbers of animals potentially exposed to sound levels sufficient to cause disturbance (i.e., are considered takes) have almost always been much lower than predicted and authorized takes. For example, during an NSF-funded, ~5000-km, 2-D seismic survey conducted by the *Langseth* off the coast of North Carolina in September–October 2014, only 296 cetaceans were observed within the predicted 160-dB zone and potentially taken, representing <2% of the 15,498 takes authorized by NMFS (RPS 2015). During an USGS-funded, ~2700 km, 2-D seismic survey conducted by the *Langseth* along the U.S. east coast in August–September 2014, only 3 unidentified dolphins were observed within the predicted 160-dB zone and potentially taken, representing <0.03% of the 11,367 authorized takes (RPS 2014b). Furthermore, as defined, all animals exposed to sound levels >160 dB are Level B 'takes' whether or not a behavioral response occurred. The EZs, which are based on predicted sound levels, are thought to be conservative; thus, not all animals detected within the EZs would be expected to have been exposed to actual sound levels >160 dB.

***Sea Turtles*.—**In § 3.4.7, the PEIS concluded that with implementation of the proposed monitoring and mitigation measures, no significant impacts of airgun operations are likely to sea turtle populations in any of the analysis areas, and that any effects are likely to be limited to short-term behavioral disturbance and short-term localized avoidance of an area of unknown size near the active airguns. In decades of seismic surveys carried out by the *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related sea turtle injuries or mortality. Four species of sea turtles could be encountered in the proposed survey areas. Given the proposed activity, no significant impacts on sea turtles would be expected.

4.1.2 Direct Effects on Marine Invertebrates, Fish, and Fisheries, and Their Significance

Effects of seismic sound on marine invertebrates (crustaceans and cephalopods), marine fish, and their fisheries are discussed in § 3.2.4 and § 3.3.4 and Appendix D of the PEIS. Relevant new studies on the effects of sound on marine invertebrates, fish, and fisheries that have been published since the release of the PEIS are summarized below. Although research on the effects of exposure to airgun sound on marine invertebrates and fishes is increasing, many data gaps remain (Hawkins et al. 2015).

4.1.2.1 Effects of Sound on Marine Invertebrates

Fewtrell and McCauley (2012) exposed captive squid (*Sepioteuthis australis*) to pulses from a single airgun; the received sound levels ranged from 120 to 184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the squid were seen to discharge ink or change their swimming pattern or vertical position in the water column. Solé et al. (2013) exposed four caged cephalopod species to low-frequency (50–400 Hz) sinusoidal wave sweeps (with a 1-s sweep period for 2 h) with received levels of 157 ± 5 dB re 1 µPa, and peak levels up to 175 dB re 1 µPa. Besides exhibiting startle responses, all four species examined received damage to the statocyst, which is the organ responsible for equilibrium and movement. The animals showed stressed behavior, decreased activity, and loss of muscle tone.

When New Zealand scallop (*Pecten novaezelandiae*) larvae were exposed to recorded seismic pulses, significant developmental delays were reported, and 46% of the larvae exhibited body abnormalities; it was suggested that the malformations could be attributable to cumulative exposure (de Soto et al. 2013). Their experiment used larvae enclosed in 60-mL flasks suspended in a 2-m diameter by 1.3-m water depth tank and exposed to a playback of seismic sound at a distance of 5–10 cm. Other studies conducted in the field have shown no effects on Dungeness crab larvae or snow crab embryos (Pearson et al. 1994; DFO 2004).

Celi et al. (2013) exposed captive red swamp crayfish (*Procambarus clarkia*) to linear sweeps with a frequency range of 0.1–25 kHz and a peak amplitude of 148 dB re 1 µPa rms at 12 kHz for 30 min. They found that the noise exposure caused changes in the haemato-immunological parameters (indicating stress) and reduced agonistic behaviors.

4.1.2.2 Effects of Sound on Fish

Potential impacts of exposure to airgun sound on marine fishes have been reviewed by Popper (2009), Popper and Hastings (2009a,b), and Fay and Popper (2012); they include pathological, physiological, and behavioral effects. Radford et al. (2014) suggested that masking of key environmental sounds or social signals could also be a potential negative effect from sound. Popper et al. (2014) presented guidelines for seismic sound level thresholds related to potential effects on fish. The effect types discussed include mortality, mortal injury, recoverable injury, temporary threshold shift, masking, and behavioral effects. Seismic sound level thresholds were discussed in relation to fish without swim bladders, fish with swim bladders, and fish eggs and larvae.

Bui et al. (2013) examined the behavioral responses of Atlantic salmon (*Salmo salar* L.) to light, sound, and surface disturbance events. They reported that the fish showed short-term avoidance responses to the three stimuli. Salmon that were exposed to 12 Hz sounds and/or surface disturbances increased their swimming speeds.

Peña et al. (2013) used an omnidirectional fisheries sonar to determine the effects of a 3-D seismic survey off Vesterålen, northern Norway, on feeding herring (*Clupea harengus*). They reported that herring schools did not react to the seismic survey; no significant changes were detected in swimming speed, swim direction, or school size when the drifting seismic vessel approached the fish from a distance of 27 km to 2 km over a 6-h period. Peña et al. (2013) attributed the lack of response to strong motivation for feeding, the slow approach of the seismic vessel, and an increased tolerance to airgun sounds.

Miller and Cripps (2013) used underwater visual census to examine the effect of a seismic survey on a shallow-water coral reef fish community in Australia. The census took place at six sites on the reef before and after the survey. When the census data collected during the seismic program were combined with historical data, the analyses showed that the seismic survey had no significant effect on the overall abundance or species richness of reef fish. This was in part attributed to the design of the seismic survey (e.g., ≥400 m buffer zone around reef), which reduced the impacts of seismic sounds on the fish communities by exposing them to relatively low SELs (<187 dB re 1 $\mu Pa^2 \cdot s$). Fewtrell and McCauley (2012) exposed pink snapper (*Pagrus auratus*) and trevally (*Pseudocaranx dentex*) to pulses from a single airgun; the received sound levels ranged from 120 to 184 dB re 1 dB re 1 $\mu Pa^2 \cdot s$ SEL. Increases in alarm responses were seen in the fish at SELs >147–151 dB re 1 $\mu Pa^2 \cdot s$; the fish swam faster and formed more cohesive groups in response to the airgun sounds.

Hastings and Miksis-Olds (2012) measured the hearing sensitivity of caged reef fish following exposure to a seismic survey in Australia. When the auditory evoked potentials (AEP) were examined for fish that had been in cages as close as 45 m from the pass of the seismic vessel and at water depth of 5 m, there was no evidence of TTS in any of the fish examined, even though the cumulative SELs had reached 190 dB re 1 $\mu Pa^2 \cdot s$.

Popper et al. (2013) conducted a study that examined the effects of exposure to seismic airgun sound on caged pallid sturgeon (*Scaphirhynchus albus*) and paddlefish (*Polyodon spathula*); the maximum received peak SPL in this study was 224 dB re 1 µPa. Results of the study indicated no mortality, either during or seven days after exposure, and no statistical differences in effects on body tissues between exposed and control fish.

Andrews et al. (2014) conducted functional genomic studies on the inner ear of Atlantic salmon (*Salmo salar*) that had been exposed to seismic airgun sound. The airguns had a maximum SPL of ~145 dB re 1 $\mu Pa^2/Hz$ and the fish were exposed to 50 discharges per trial. The results provided evidence that fish exposed to seismic sound either increased or decreased their expressions of different genes, demonstrating that seismic sound can affect fish on a genetic level.

4.1.2.3 Effects of Sound on Fisheries

Handegard et al. (2013) examined different exposure metrics to explain the disturbance of seismic surveys on fish. They applied metrics to two experiments in Norwegian waters, during which fish distribution and fisheries were affected by airguns. Even though the disturbance for one experiment was greater, the other appeared to have the stronger SEL, based on a relatively complex propagation model. Handegard et al. (2013) recommended that simple sound propagation models should be avoided and that the use of sound energy metrics like SEL to interpret disturbance effects should be done with caution. In this case, the simplest model (exposures per area) best explained the disturbance effect.

Hovem et al. (2012) used a model to predict the effects of airgun sounds on fish populations. Modeled SELs were compared with empirical data and were then compared with startle response levels for cod. This work suggested that in the future, particular acoustic-biological models could be useful in designing and planning seismic surveys to minimize disturbance to fishing. Their preliminary analyses indicated that seismic surveys should occur at a distance of 5–10 km from fishing areas, in order to minimize potential effects on fishing.

In their introduction, Løkkeborg et al. (2012) described three studies in the 1990s that showed effects on fisheries. Results of a study off Norway in 2009 indicated that fishes reacted to airgun sound based on observed changes in catch rates during seismic shooting; gillnet catches increased during the seismic shooting, likely a result of increased fish activity, whereas longline catches decreased overall (Løkkeborg et al. 2012).

4.1.2.4 Conclusions for Invertebrates, Fish, and Fisheries

This newly available information does not affect the outcome of the effects assessment as presented in the PEIS. The PEIS concluded that there could be changes in behavior and other non-lethal, short-term, temporary impacts, and injurious or mortal impacts on a small number of individuals within a few meters of a high-energy acoustic source, but that there would be no significant impacts of NSF-funded marine seismic research on populations. The PEIS also concluded that seismic surveys could cause temporary, localized reduced fish catch to some species, but that effects on commercial and recreation fisheries were not significant.

Interactions between the proposed survey and fishing operations in the proposed survey areas are expected to be limited. Two possible conflicts in general are the *Langseth*'s streamer entangling with fishing gear and displacement of fishers from the proposed survey areas. Fishing activities could occur within the proposed survey areas; however, a safe distance would need to be kept from the *Langseth* and the towed seismic equipment. Conflicts would be avoided through communication with the fishing community during the survey.

At least 64 OBSs would be deployed during the proposed survey and would be recovered after the survey has been completed. The OBS anchors either are 23-kg pieces of hot-rolled steel that have a footprint of 0.3×0.4 m or 36-kg iron grates with a footprint of 0.9×0.9 m. OBS anchors would be left behind upon equipment recovery. Although OBS placement would disrupt a very small area of seafloor habitat and could disturb benthic invertebrates, the impacts are expected to be localized and transitory, and no population-level effects are expected.

Given the proposed activity, no significant impacts on marine invertebrates, marine fish, and their fisheries would be expected. In decades of seismic surveys carried out by the *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have not observed any seismic sound-related fish or invertebrate injuries or mortality.

4.1.3 Direct Effects on Seabirds and Their Significance

Effects of seismic sound and other aspects of seismic operations (collisions, entanglement, and ingestion) on seabirds are discussed in § 3.5.4 of the PEIS. The PEIS concluded that there could be transitory disturbance, but that there would be no significant impacts of NSF-funded marine seismic research on seabirds or their populations. Given the proposed activity, no significant impacts on seabirds would be expected. In decades of seismic surveys carried out by the *Langseth* and its predecessor, the R/V *Ewing*, PSOs and other crew members have seen no seismic sound-related seabird injuries or mortality.

4.1.4 Indirect Effects on Marine Mammals, Sea Turtles, Seabirds and Fish and Their Significance

The proposed seismic operations would not result in any permanent impact on habitats used by marine mammals, sea turtles, or seabirds or to the food sources they use. The main impact issue associated with the proposed activity would be temporarily elevated noise levels and the associated direct effects on these species, as discussed above.

During the proposed seismic surveys, only a small fraction of the available habitat would be ensonified at any given time. Disturbance to fish species and invertebrates would be short-term, and fish would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed survey would have little impact on the abilities of marine mammals or sea turtles to feed in the area where seismic work is planned. No significant indirect impacts on marine mammals, sea turtles, or fish would be expected.

4.1.5 Direct Effects on Recreational SCUBA Divers and Dive Sites and Their Significance

Most of the proposed survey areas are in water depths too great (>100 m) for recreational diving Significant impacts on, or conflicts with, divers or diving activities in shallow waters would be avoided through communication with the diving community before and during the survey. In particular, dive operators would be made aware of operations near dive sites.

4.1.6 Cumulative Effects

According to Nowacek et al. (2015), cumulative impacts have a high potential of disturbing marine mammals. Wright and Kyhn (2014) proposed practical management steps to limit cumulative impacts, including minimizing exposure by reducing exposure rates and levels. The results of the cumulative impacts analysis in the PEIS indicated that there would not be any significant cumulative effects to marine resources from the proposed NSF-funded marine seismic research, including the combined use of airguns with MBES, SBP, and acoustic pingers. However, the PEIS also stated that, "A more detailed, cruise-specific cumulative effects analysis would be conducted at the time of the preparation of the cruise-specific EAs, allowing for the identification of other potential activities in the areas of the proposed seismic surveys that may result in cumulative impacts to environmental resources." Here we focus on activities that could impact animals specifically in the proposed survey areas (e.g., research activities, vessel traffic, and commercial fisheries).

4.1.6.1 Past and future research activities in the area

The value of this region as a natural laboratory for earthquake studies is widely recognized by the scientific community, as evidenced by a number of amphibious natural source and large aperture seismic experiments in the region in the past 20 years (conducted primarily by Germany in collaboration with Chilean scientists). However, existing reflection data provide good structural details only for the shallow structures, and existing refraction data are not able to resolve the deep structure sufficiently to map the subducting plate, plate boundary, or upper plate structure in detail. Due to the short (3-km) source-receiver offsets and weak seismic source, the R/V *Conrad* seismic reflection data acquired in 1988 do not have adequate signal strength for deep penetration or the specifications to enhance signals with advanced data processing, especially water-column multiple suppression. In 2012, Dr. A. Trehu conducted a low energy seismic survey off of Maule, Chile to study how the outer accretionary wedge was responding to a change in stress resulting from a megathrust earthquake that occurred on 27 February 2010. The low energy seismic source was active for ~149 h (~6 days) during 1105 km of survey tracklines (SIO 2012). Monitoring and mitigation measures were implemented during the survey; the majority of sightings and mitigation measures implemented were for pinnipeds.

Other scientific seismic research activities could be conducted in this region in the future; however, aside from those that are covered in this EA, no other marine geophysical surveys using the *Langseth* are currently proposed in the region in the foreseeable future. At the present time, the proponents of the survey are not aware of other marine research activities planned to occur in the proposed survey areas during 2016, or beyond, but research activities planned by other entities are possible.

4.1.6.2 Vessel traffic

Vessel traffic in and around the proposed survey areas would primarily consist of commercial shipping vessels, with the addition of fishing, recreational, passenger, tug/towing/pilot, military, and research vessels, particularly in the nearshore portions of the area. Based on data made available through the Automated Mutual-Assistance Vessel Rescue (AMVER) system managed by the U.S. Coast Guard, fewer than 4 commercial vessels per month typically passed through the northern proposed survey area during 2007–2013, although up to 14 vessels per month were occasionally observed (2013 data are available for January–June, the most recent data available as of September 2015) (USCG 2013). Between 4 and 49 commercial vessels per month passed through the central proposed survey area during this period, with the greatest amount of traffic generally observed in spring or summer (USCG 2013). Five to 14 commercial vessels per month generally passed through the southern proposed survey area during this period, occasionally increasing up to 49 vessels (USCG 2013). According to Colpaert et al. (2015), ship traffic has increased considerably in the Chiloé-Corcovado area over the last decade.

Live vessel traffic information is available from MarineTraffic (2015) and FleetMon (2015), including vessel names, types, flags, positions, and destinations. MarineTraffic (2015) and FleetMon (2015) were accessed on 22 and 24 September and 23 November 2015. No vessels were observed near the proposed survey areas when FleetMon (2015) was accessed. On MarineTraffic (2015), several vessels were observed near the northern proposed survey area, including tankers (3), bulk carriers (8), general cargo ships (3), container ships (4), and unidentified vessels (2). Both unidentified vessels and one of the bulk carriers had a Chilean flag; all remaining vessels had foreign flags. A greater number of vessels were observed near the central proposed survey area, including container ships (4), oil/chemical tankers (9), timber carriers (1), asphalt/bitumen tankers (1), general tankers (3), bulk carriers (7), tug/towing/pilot vessels (13), fishery research vessels (1), fishing vessels (2), pleasure craft (1), and military vessels (1). All of the tug/towing/pilot, fishery research, fishing, pleasure, and military vessels had Chilean flags; the remaining vessels were Chilean or foreign flagged. Numerous vessels were also observed in the vicinity of the southern proposed survey area, including container/cargo ships (19), bulk carriers (10), fish carriers (12), chemical tankers (2), vehicle carriers (2), wood chip carriers (2), livestock carriers (1), fishing vessels (18), factory trawlers (1), tug/towing/pilot vessels (10), passenger ships (11), military vessels (1), research survey vessels (1), pleasure craft (9), and unspecified vessels (3). All of the fish carriers, factory trawlers, and fishing, tug/towing/pilot, military, and research survey vessels, and most passenger, pleasure, and unspecified vessels had Chilean flag. The remaining vessels were Chilean or foreign flagged.

There are several ports of call used by cruise ships throughout Chile (What's In Port 2012), including 3 near the northern proposed survey area (Arica, Iquique, and Antofagasta), 1 near the central proposed survey area (Coquimbo), and 6 near the southern proposed survey area (Valparaíso, Talcahuano, Valdivia Puerto Corral, Ancud, Castro Chiloé Island, and Puerto Montt).

The total transit distance of ~11,500 km (including transit to and from port, and OBS deployment/ recovery) by L-DEO's vessel *Langseth* would be small relative to total transit length for vessels operating in the general region around the proposed survey areas. Thus, the addition of L-DEO's vessel traffic to existing shipping and fishing operations (see below) is expected to result in a only a minor increase in overall ship traffic.

4.1.6.3 Military Activity

The Chilean Navy operates out of five bases (Naval Zones) throughout Chile: Iquique at ~20.3°S, Talcahuano at ~36.7°S, Valparaíso at ~33°S, Puerto Montt at 41.5°S, and Punta Arenas at ~53°S (Santos 2014). Two Chilean military vessels were observed, one in the central and one in the southern proposed survey area, when MarineTraffic.com was accessed in September and November 2015 (see above): the LSG *San Antonio* and LSG *Puerto Montt*, both general service vessels with a length of 33 m.

There have been several military exercises that have either occurred near the proposed survey areas or otherwise involved Chilean naval forces that may have transited through them during April–June 2015. These included search and rescue missions including off Puerto Montt; drills including coastline combat, an amphibious landing, and a man overboard simulation in the Region of Magallanes; a gathering of several National Fleet ships in Iquique; and a naval exercise in Puerto Montt (Diálogo 2015b; NAFC 2015). There are no known conflicts with the Proposed Action with future Chilean military activities; through the U.S. State Department, L-DEO is seeking authorization from Chile for clearance to operate in support of the research activity within its EEZ.

4.1.6.4 Fisheries

The commercial fisheries in the general area of the proposed survey are described in § III. The primary contributions of fishing to potential cumulative impacts on marine mammals and sea turtles involve noise, potential entanglement, and removal of prey items (e.g., Reeves et al. 2003). There might be some localized avoidance by marine mammals of fishing vessels near the proposed survey areas.

The capture, possession, and trade of small cetaceans are prohibited in Chile; however, incidental bycatch mortality remains an issue (Reyes and Oporto 1994). There are confirmed reports of killer whale, sperm whale, and southern right whale dolphin entanglements in the Chilean swordfish fishery (Reyes and Oporto 1994). Marine mammal entanglements in the Chilean ratfish and sciaenid fishery typically occur during night or early morning. The two primary species caught between 1988 and 1990 were Burmeister's porpoise (159) and Chilean dolphin (146); Peale's dolphin (3) was also taken as bycatch. Animals caught are often used as bait and occasionally used for human consumption.

Limited opportunistic sampling indicates that fisheries-related kills, including directed takes, affect several cetacean species at unknown levels (Van Waerebeek et al. 1999). Van Waerebeek et al. (1999) indicate that despite the moratorium on the capture of cetaceans in Chilean waters, small cetacean takes have periodically been documented in Chile. These include, most notably, the hunting of Peale's dolphin, the Chilean dolphin, and Commerson's dolphin for crab bait in southern Chile, and harpooning and net entanglements of southern right whale dolphins off central and northern Chile. Van Waerebeek et al. (1999) described nine cases of confirmed bycatch, suspected bycatch, or confirmed intentional take in north-central Chile; the species targeted included Burmeister's porpoise (3) and the pygmy sperm whale (3), long-beaked common dolphin (1), long-finned pilot whale (1), and pygmy beaked whale (1).

Common bottlenose and common dolphins, as well as Burmeister's porpoise, are also taken as bycatch in fisheries in Peru (Mangel et al. 2008).

A review of marine mammal bycatch in the gillnet fishery pre-1990 and during 1990–2010 identified four species caught off the coast of Chile (Reeves et al. 2013). Chilean dolphins were reported as bycatch in 1989, and 116 were caught in 1990–1991. Two southern right whale dolphins were reported caught in 1990, 450 Burmeister's porpoise were caught off Chile and Peru combined in 1989, and 134 were caught off Chile in 1990–1991 (Reeves et al. 2013). In addition, one minke whale was reported caught in 2004 (Reeves et al. 2013).

Sea turtles are taken as bycatch in fisheries off Peru and Chile (Donoso and Dutton 2010; Alfaro-Shigueto et al. 2011; Sarmiento-Devia et al. 2015); the bycatch rates in the region are some of the highest throughout the world (Wallace et al. 2010; Alfaro-Shigueto et al. 2011; Sarmiento-Devia et al. 2015). Donoso and Dutton (2010) presented data on sea turtles caught in the Chilean longline fishery targeting swordfish in International Waters between 2001 and 2005. Leatherback turtles (284) and loggerhead turtles (59) were caught in <4% and 1% of the sets, respectively. Most leatherback turtles (97.5%) were caught between 24°S and 38°S, whereas loggerhead turtles were primarily caught between 24.3°S and 25.5°S. Sarmiento-Devia et al. (2015) reported 749 bycatch records up until December 2013 in Chile, most of which were leatherbacks (569), followed by loggerhead turtles (81).

There might be some localized avoidance by marine mammals of fishing vessels near the proposed survey areas. L-DEO's operations in the proposed survey areas are limited in duration (total of ~80 days), and the addition of L-DEO's operations to existing commercial fishing operations is expected to result in only a negligible increase in overall disturbance effects on marine mammals and sea turtles and no increase in serious injuries or mortality in marine mammals or sea turtles.

4.1.6.5 Oil and Gas Industry

In most Latin American countries, hydrocarbons are an asset of the state, and state-owned oil and gas companies are responsible for conducting extraction and development activities. In recent years, however, several countries have introduced regulatory reforms to allow for increased participation of the private sector in oil and gas production activities. Chile's Empresa Nacional del Petróleo (ENAP) was established in June 1950, following the discovery of the country's first oil well in the Springhill area in Magallanes in December 1945. ENAP has partnered with international oil companies in recent years and current exploration and exploitation activity is focused in the Magallanes and Tierra del Fuego regions, in the south of the country, away from the proposed survey areas.

To the north of the proposed survey areas, Peru offshore oil and gas exploration has mainly occurred in the northern part of the country, but recent activity in the central and southern regions have increased, including prospecting seismic surveys in 2014 in advance of a 2014 lease block bidding round. Seismic survey activity plans for 2016/2017 are currently not available, but any activities would occur well north of the proposed survey areas.

4.1.7 Unavoidable Impacts

Unavoidable impacts to the species of marine mammals and turtles occurring in the proposed survey areas would be limited to short-term, localized changes in behavior of individuals. For cetaceans, some of the changes in behavior may be considered to fall within the MMPA definition of "Level B Harassment" (behavioral disturbance; no serious injury or mortality). TTS, if it occurs, would be limited to a few individuals, is a temporary phenomenon that does not involve injury, and is unlikely to have long term consequences for the few individuals involved. No long-term or significant impacts would be expected on any of these individual marine mammals or turtles, or on the populations to which they belong. Effects on recruitment or survival would be expected to be (at most) negligible.

4.1.8 Coordination with Other Agencies and Processes

This Draft EA has been prepared by LGL on behalf of L-DEO and NSF pursuant to Executive Order 12114. Potential impacts to endangered species and critical habitat have also been assessed in the document; therefore, it will be used to support the ESA Section 7 consultation process with NMFS and USFWS. This document will also be used as supporting documentation for an IHA application submitted by L-DEO to NMFS, under the U.S. MMPA, for "taking by harassment" (disturbance) of small numbers of marine mammals, for the proposed seismic surveys. Through the U.S. Department of State, L-DEO is seeking authorization from Chile for clearance for the *Langseth* to operate in support of the research activity within its EEZ.

4.2 No Action Alternative

An alternative to conducting the proposed activity is the "No Action" Alternative, i.e., do not issue an IHA and do not conduct the operations. If the research were not conducted, the "No Action" alternative would result in no disturbance to marine mammals or sea turtles attributable to the proposed activity; however, valuable data about the marine environment would be lost. Research that would contribute to understanding of the geologic controls on megathrust slips that cause earthquakes would not be gained. The No Action Alternative would not meet the purpose and need for the proposed activity.

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